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Human Factors Assessment of the UH-60M Common Avionics Architecture System (CAAS) Crew Station During the Limited User Evaluation (LEUE)

by Thomas J. Havir, David B. Durbin, and Lorraine J. Frederick

ARL-MR-0634 **December 2005**

NOTICES

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Aberdeen Proving Ground, MD 21005-5425

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Human Research and Engineering Directorate, ARL

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14. ABSTRACT
The UH-60M Product Office requested the U.S. Army Research Laboratory's (ARL's) Human Research and Engineering Directorate to participate in the Limited Early User Evaluation (LEUE) of the Common Avionics Architecture System (CAAS) cockpit. ARL conducted a human factors evaluation (HFE) during the LEUE, which assessed workload, situation awareness, simulator sickness, pilot-vehicle interface (PVI), and eye tracker data. The data were used to identify characteristics of the CAAS cockpit that enhance or degrade pilot performance. Characteristics that degrade pilot performance should be considered for design changes at the earliest opportunity.
Three utility helicopter (UH)-60 crews (six pilots) each conducted three mission scenarios for a total of nine flights. The three missions consisted of flights in visual meteorological conditions (VMC), instrumented meteorological conditions (IMC), and tactical conditions. The pilots completed the simulator sickness questionnaire before and after each flight. They completed the Bedford Workload Rating Scale, Situation Awareness (SA) Rating Technique, and the PVI Questionnaire after each mission. In addition to pilot data, a tactical steering committee (TSC) was used to perform an independent assessment of workload, situation awareness, and mission success. The TSC completed a survey after each mission. The data were analyzed with the use of the Wilcoxon Signed Ranks Test to compare pilot ratings between seat position and results between instrument flight rule (IFR) and visual flight rule (VFR) flights.
The mean workload rating for all tasks was 3.10, indicating that the pilots typically had enough workload capacity for all desirable additional tasks. The mean situation awareness rating provided by the pilots was 25.84. This SA rating indicates that the pilots felt they had moderate levels of situation awareness during the missions. The pilots also provided a lot of data and comments regarding the PVI and offered recommendations for design improvements. Finally, the eye tracker results showed that the flying pilot was focused out the window 60.86% of the time, while the non-flying pilot spent only 26.30% focused out the window.
The results of the assessment concluded that the CAAS cockpit resulted in acceptable workload and situation awareness levels; however, several issues were identified that, if corrected, could offer significant reductions in workload and improve pilot performance. These issues should be considered for future modifications of the CAAS design, and future HFEs should be conducted to evaluate the effectiveness of any design changes.

15. SUBJECT TERMS
Black Hawk; CAAS; human factors; pilot workload; UH-60

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From the UH-60M Product Office (PO), the authors would like to thank Mr. Dave Arterburn for his invaluable assistance during the evaluation and Mr. Detlef Presser for giving us the opportunity to participate in this evaluation and provide critical human factors data to the product manager. Last, but certainly not least, we would like to thank Mr. Nick Nickles who works as a contractor for Quantitech in support of the UH-60M PO. Mr. Nickles was very helpful in preparing for this evaluation and helping create the surveys required to collect the human factors data.

The authors would like to recognize several individuals from the Systems Simulation and Development Directorate (SSDD) of the Aviation and Missile Research, Development, and Engineering Center (AMRDEC): Will Nikonchuk and Dena Childress were the Government leaders for the Advanced Prototyping, Engineering, and Experimentation Laboratory during the limited early user evaluation (LEUE). Their support for the UH-60M program and MANPRINT has been unwavering over the years.

The LEUE would not have been possible without the efforts of the crew from Science Applications International Corporation. These personnel created an incredible software prototype of the CAAS cockpit that allowed us to conduct a sophisticated flight simulation of the UH-60M CAAS crew station. Special thanks are owed to Eric Thomas who was responsible for the eye tracker system. Eric's hard work allowed us to successfully integrate the eye tracker system in the Battlefield Highly Immersive Virtual Environment and collect some great data.

We would also like to thank personnel from the Aviation and Missile Command at Redstone Arsenal, Alabama. Mr. Dan Francis of AMRDEC is the Aviation Engineering Directorate crew station engineer. His cooperation with the U.S. Army Research Laboratory over the course of the UH-60M program has been appreciated.

Finally and most importantly, our thanks to our six participants, who shall remain unnamed for scientific protocol reasons. Professional Army aviators all, they and their comrades are the reason that all of us work so diligently on this aircraft.

1. Introduction

1.1 Background and Purpose

The utility helicopter (UH)-60 Black Hawk is a twin-turbine engine, single rotor, semimonocoque fuselage, rotary wing helicopter capable of transporting cargo, 11 combat troops, and weapons during day and night, instrument meteorological conditions (IMC), visual meteorological conditions (VMC), and degraded visual environment conditions (see figure 1). The main and tail rotor systems consist of four blades each, with the capability to manually fold the main rotor blades, scissor the tail rotor paddles, and fold the tail pylon assembly for deployment, transport, or storage. A movable, horizontal folding stabilator assembly is situated on the lower portion of the tail rotor pylon to provide enhanced flight characteristics.

Figure 1. UH-60M Black Hawk helicopter.

The UH-60 Black Hawk helicopter provides air assault, general support, and medical evacuation (MEDEVAC) capabilities for the U.S. Army. The UH-60 also supports the Army Airborne Command and Control System and special operations. The UH-60A and UH-60L model Black Hawk helicopters were first fielded in the 1970s and are approaching the end of their useful service life. Increasing operations and support costs and decreasing operational readiness are consequences of the aging fleet. The UH-60M program, formerly a recapitalization program of existing airframes, is now a new production program designed to improve the life of the current system, reduce operations and support costs, and increase operational readiness. Additionally, the UH-60M will meet future digitization and situational awareness (SA) requirements, increase the lift and range capabilities of the current aircraft, and provide an improved platform for the HH-60M MEDEVAC helicopter.

General Shoomaker, U.S. Army Chief of Staff, and General Cody, Vice Chief of Staff, have challenged the Army aviation community to integrate the Common Avionics Architecture System (CAAS), developed by the 160th Special Operations Aviation Regiment in 2003, into

future improvements of the UH-60M Black Hawk. The CAAS configuration includes four portrait-style multi-function displays (MFDs), two control display units (CDUs), two data concentrators, and two general purpose processing units (see figure 2).

Figure 2. Conceptual CAAS configuration.

In accordance with the direction to integrate CAAS, the UH-60M PO conducted a limited early user evaluation (LEUE) to evaluate the integration of the CAAS in the UH-60M crew station. The primary objectives of this evaluation were to

- Provide a system engineering early risk reduction evaluation to assess the four MFD versions of CAAS in the UH-60M Black Hawk.
- Obtain feedback from pilots for initial assessments of the CAAS.
- Provide insight into emerging capabilities of the UH-60M CAAS cockpit.

At the request of the UH-60M PMO, the U.S. Army Research Laboratory's (ARL's) Human Research and Engineering Directorate conducted a human factors evaluation (HFE) of the UH-60M CAAS crew station during the LEUE. The HFE focused on workload, SA, and pilot-vehicle interface (PVI). Additional data collection included eye tracker data, simulator sickness data, and tactical steering committee (TSC) ratings.

The purpose of this report is to summarize the human factors data collected during the LEUE by ARL.

1.2 Assessment of Crew Workload

A common definition of pilot workload is "the integrated mental and physical effort required to satisfy the perceived demands of a specified flight task" (Roscoe, 1985). It is important to assess pilot workload because mission accomplishment is related to the mental and physical ability of

the crew to effectively perform their flight and mission tasks. If one or both pilots experience excessively high workload while performing flight and mission tasks, the tasks may be performed ineffectively or abandoned. In order to assess whether the pilots are task overloaded during the mission profiles, the level of workload for each pilot must be evaluated.

1.2.1 Bedford Workload Rating Scale

The pilots completed the Bedford Workload Rating Scale (BWRS) (appendix A) immediately after each mission to estimate the level of workload that they experienced during missions. The pilots used the BWRS to rate the workload needed to accomplish 28 UH-60M aircrew training manual (ATM) tasks (appendix A). The ATM tasks were selected by personnel from ARL, the UH-60M PO, and the U.S. Army Training and Doctrine Command System Manager (TSM) for utility aircraft because they were estimated to have the most impact on pilot workload during the planned missions.

The BWRS has been used extensively by the military, civil, and commercial aviation communities for pilot workload estimation (Roscoe & Ellis, 1990). It requires pilots to rate the level of workload associated with a task, based on the amount of spare capacity they feel they have to perform additional tasks. Spare workload capacity is an important commodity for pilots because they are often required to perform several tasks concurrently. For example, pilots often perform navigation tasks, communicate via multiple radios, monitor aircraft systems, and assist the pilot with the controls to perform flight tasks (e.g., maintain air space surveillance) within the same time interval. Mission performance is reduced if pilots are task saturated and have little or no spare capacity to perform other tasks. Integration of the UH-60M CAAS crew station should help ensure that pilots can maintain adequate spare workload capacity while performing flight and mission tasks.

1.3 Assessment of Crew Situational Awareness (SA)

SA can be defined as the pilot's mental model of the current state of the flight and mission environment. A more formal definition is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). It was important to assess SA during the LEUE because it had a direct impact on pilot and system performance. Good SA should increase the probability of good decision making and performance by air crews when they perform flight and mission tasks in the UH-60M CAAS.

1.3.1 Situation Awareness Rating Technique (SART)

The SART (appendix B) is a multi-dimensional rating scale for operators to report their perceived SA. The SART was developed as an evaluation tool for the design of air crew systems (Taylor, 1989) and examines three components of SA: understanding, supply, and demand. Taylor proposed that SA depends on the pilot's understanding (U) (e.g., quality of information

he receives) and the difference between the demand (D) on the pilot's resources (e.g., complexity of mission) and the pilot's supply (S) (e.g., ability to concentrate). When D exceeds S, there is a negative effect on U and an overall reduction of SA. The formula SA = U - (D - S) is used to derive the overall SART score. The SART is one of the most thoroughly tested rating scales for estimating SA (Endsley, 2000).

1.4 Assessment of Pilot-Vehicle Interface (PVI)

The crew station PVI directly impacts crew workload and SA during a mission. A crew station that is designed to augment the cognitive and physical abilities of crews will minimize workload, enhance SA, and contribute to successful mission performance. The pilots completed a PVI questionnaire after each mission (appendix C) to identify any problems with the usability of the controls, displays, or subsystems.

1.5 Assessment of Simulator Sickness

Simulator sickness has been defined as a condition where pilots suffer physiological discomfort in the simulator but not while flying the actual aircraft (Kennedy, Lilienthal, Berbaum, Balzley, & McCauley, 1989). It is generally believed that simulator sickness is caused by a mismatch either between the visual and vestibular sources of information about self-motion, or between the sensory information (e.g., acceleration cues) presented by the simulator and the sensory information presented by the primary aircraft that the pilot operates. When the sensory information presented by the simulator does not match the aircraft, the pilot's nervous system reacts adversely to the sensory mismatch and the pilot begins to experience discomfort. Characteristics of simulator sickness include nausea, dizziness, drowsiness, and several other symptoms (Kennedy et al., 1989). It is important to assess simulator sickness because the discomfort felt by pilots can be distracting. Pilot distraction is one of the operational consequences of simulator sickness listed by Crowley (1987). If pilots are distracted by the discomfort they feel during missions, their performance is likely to suffer. Additionally, the discomfort could influence the perceived levels of workload and SA that the pilots experienced during a mission.

1.5.1 Simulator Sickness Questionnaire (SSQ)

The SSQ (appendix D) was administered to the pilots to estimate the severity of physiological discomfort that they experienced during missions and help assess whether they were being distracted by the discomfort. The SSQ (Kennedy, Lane, Berbaum, & Lilienthal, 1993) is a checklist of 16 symptoms. These symptoms are categorized into three subscales: oculomotor (e.g., eyestrain, difficulty focusing, blurred vision), disorientation (e.g., dizziness, vertigo), and nausea (e.g., nausea, increased salivation, burping). The three subscales are combined to produce a total severity score. The total severity score is an indicator of the overall discomfort that the pilots experienced during the mission.

1.6 Tactical Steering Committee (TSC)

A TSC observed each mission and rated crew workload, crew SA, crew coordination, and mission success (appendix E). The TSC provided an independent assessment of the workload and SA levels experienced by the crews. They also helped identify whether problems with crew workload or crew SA contributed to lack of mission success.

For this limited evaluation, only one subject matter expert (SME) was available to serve on the TSC. This person was the UH-60 user representative from TSM-Lift at Fort Rucker, Alabama. He has substantial experience with the utility helicopter and Army aviation missions and was very knowledgeable of the UH-60M CAAS crew station design. He observed each mission from the battle master station in the Aviation and Missile Research and Development Center's (AMRDEC) Advanced Prototyping, Engineering, and Experimentation (APEX) Laboratory, Redstone Arsenal, Alabama, where he could observe crew station displays and the out-the-window (OTW) view provided to the crew. He also listened to all audio communications between crew members and outside sources during the missions. A map provided real-time status of the location of the aircraft on the terrain database.

1.7 AMRDEC APEX Laboratory

The UH-60M product manager directed the use of AMRDEC's APEX Laboratory, which provided the appropriate virtual prototyping capabilities required to perform the evaluation. The mission of the APEX Laboratory is to provide modeling and simulation support of weapon systems early in the acquisition process. This is accomplished through several means, including human-in-the-loop simulators, distributed simulation experimentation, and constructive simulation development.

The laboratory infrastructure is designed to support experimentation through a wide range of technologies. The laboratory includes a battle master or exercise control station that has access to each simulation "playing" on the network by means of a modular semi-automated forces terminal, data collection devices, headset communications, and video monitoring equipment. All exercises are conducted from the battle master station to ensure that all players are engaged in the exercise and that all data collection devices are active. The battle master station provided the exercise controller and tactical steering committee with all the information needed to coordinate the scenario-driven events and operate the data collection devices required for the LEUE. The APEX facility has a synthetic environment development team that was able to develop custom, correlated terrain databases that were designed to specifically enhance the realism of the immersive environment and support the operational scenarios for the event.

1.7.1 Battlefield Highly Immersive Virtual Environment (BHIVE)

A significant component of the APEX Laboratory is BHIVE, which was developed in support of weapon system evaluation as a high-level architecture and distributed interactive simulation

compliant, human-in-the-loop, virtual environment. It was designed with a "roll-in/roll-out[1]" capability to allow several types of devices to be integrated into the environment through a standard interface. This capability provides the flexibility to immerse multiple types of crew stations in a realistic and re-usable synthetic environment.

BHIVE is an enclosed environment that consists of a projection system, three-dimensional surround sound audio, and a plug-and-play interface for the integration of various engineering analysis devices including the UH-60M and AH-64A reconfigurable crew station, AH-1W and Z Cobra crew stations, and a tube-launched optically tracked wire-guided missile simulator mounted on a high mobility multipurpose-wheeled vehicle chassis (see figure 3). The projection system consists of a fixed base, bi-directional curved screen with three soft-edge blended projectors and an image generation system. The screen provides a field of view of 40 degrees vertical (111.61 inches) and 150 degrees horizontal (229 inches). The distance from the screen to the crew station is approximately 152 inches. BHIVE also includes a controller station, a video switching rack, and reconfigurable video cameras. BHIVE allowed the pilots and HFE experts to experiment with crew station layout designs and to perform initial SA and workload assessments.

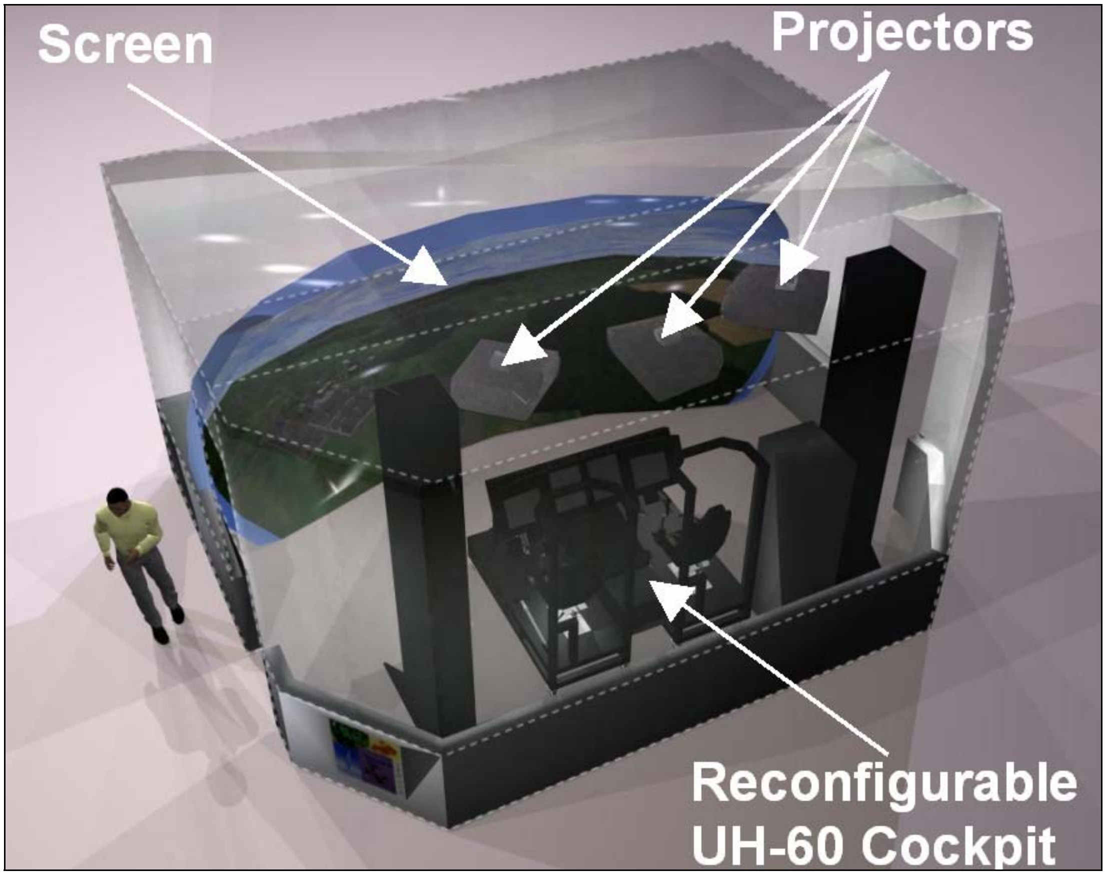

Figure 3. BHIVE configuration.

[1]This means that the crew station rolls out of the "simulator" and a person can quickly replace it with a different crew station.

1.7.2 The Reconfigurable UH-60M Crew Station

The reconfigurable UH-60M crew station was designed to provide maximum utility and usability throughout the engineering and design process. The crew station used flat panel liquid crystal displays and touch screen technology to replicate human-machine hardware interfaces for the four MFDs, two CDUs, and other control surfaces within the crew station. This configuration allowed the APEX engineers to create rapid software prototypes of the actual crew station components, based on the current design of the CAAS (see figure 4).

Figure 4. CAAS flight displays depicted on MFD.

2. Method

2.1 Participants

Participants consisted of six pilots from Fort Rucker and Redstone Arsenal. The two pilots from Redstone Arsenal were commissioned officers who were rated in the UH-60 Black Hawk but were not currently serving on flight duty. Of the pilots from Fort Rucker, two were senior warrant officers who worked as experimental test pilots at Cairns Army Airfield, one was a warrant officer who is assigned to the 1-212th Aviation Regiment, and one was a civilian flight instructor for the maintenance test pilot course. They represented a broad range of experience with total flight hours that ranged from 560 to 13,000. The relevant demographic characteristics of the pilots are listed in table 1.

Table 1. Pilot demographics (N = 6).

Summary of demographic characteristics	Age (yrs)	Flight hours in UH-60A/L Black Hawk	Total flight hours in Army aircraft
Mean	38.8	1768	3920
Median	38.5	1475	2230
Range	32 to 49	360 to 3400	560 to 13,000

2.2 Data Collection

The BWRS, SART, PVI, SSQ, and TSC questionnaires (appendices A through E) were developed in accordance with published guidelines for proper format and content (O'Brien & Charlton, 1996). A pre-test was conducted to refine the questionnaires and to ensure that they could be easily understood and completed by pilots and TSC members.

The pilots completed the PVI, workload, and SA questionnaires immediately after each mission. The pilots completed the SSQ before and after each mission. The TSC member completed the TSC questionnaire after each mission. Additional data were obtained from the pilots and the TSC member during post-mission discussions and the final after-action review (AAR). Questionnaire results were clarified with information obtained during post-mission discussions and the daily AARs.

2.2.1 Eye Tracker System

Although the data from the questionnaires were systematically gathered by widely accepted HFE methods, they were still subjective in nature. Complementary objective data were collected through a head and eye tracking system from Applied Science Laboratories (ASL). Their system was used because it was capable of integrating a laser head tracker to allow unrestricted head movement during data collection, and it was compatible with the head gear unit-56 flight helmet.

The ASL EyeHead[2] Package integrated a Model 501 eye tracker and an Ascension Laserbird[3] head tracker. This technology allowed us to collect digital data that specified point of gaze with respect to stationary objects within the crew station. The ASL software allowed data collectors to continuously monitor the eye position of the pilots by crosshairs superimposed over live imagery (see figure 5). The software also included a built-in analysis tool that allowed data to be viewed in tabular or graphical format.

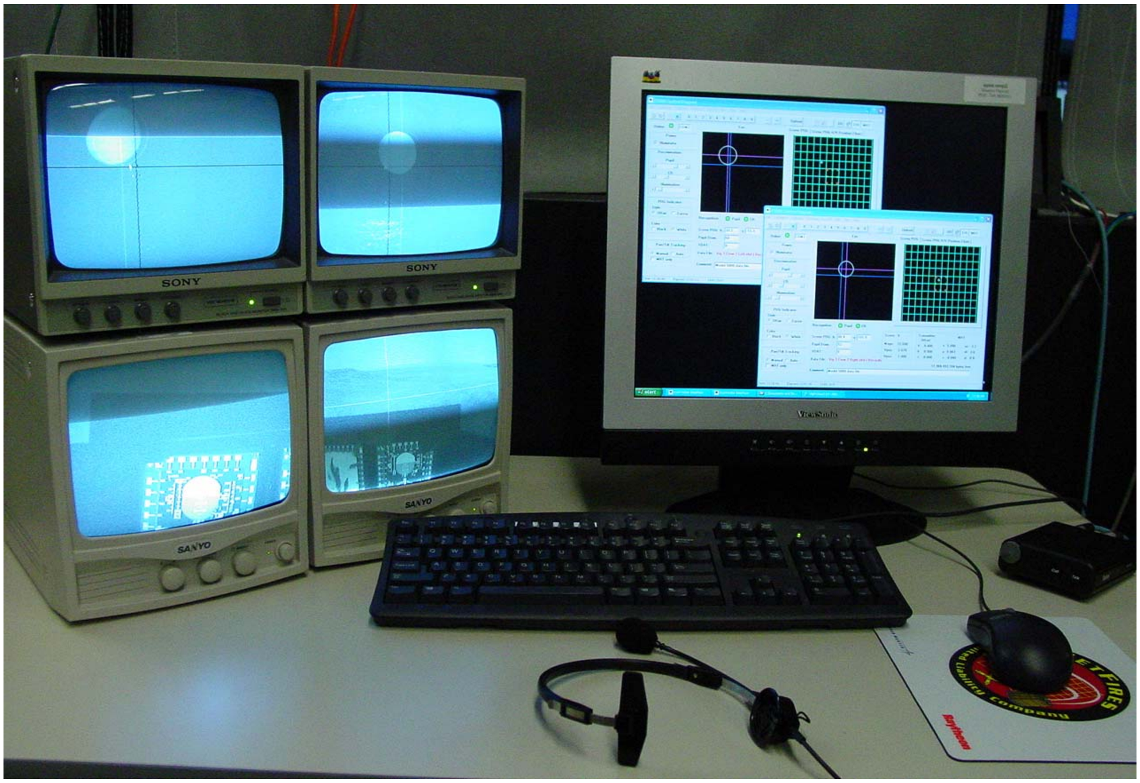

Figure 5. Eye tracker scene camera monitors and control panel interface.

2.3 Data Analysis

Pilot responses to the BWRS, SART, SSQ, and PVI questionnaires were analyzed with means and percentages. Their responses to the BWRS, SART, and SSQ were further analyzed with the Wilcoxon Signed Ranks Test (WSRT) to compare pilot ratings between seating position (left versus right). The WSRT was used to calculate probability values for data comparisons.

We summarized the eye tracker data by calculating the total percentage of fixations that were focused on different areas of interest (AOI). Four AOIs were created for each pilot: left MFD, right MFD, CDU, and OTW (see figure 6). A final category, called "Other," captured eye fixations not focused on a specific AOI. Most of the fixations captured in the "Other" category

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[2]EyeHead is a trademark of Applied Science Laboratories.

[3]Laserbird is a trademark of Ascension Technology Corporation.

resulted from the pilot looking at his kneeboard or looking across the cockpit at the other pilot's displays.

Figure 6. Eye tracker areas of interest.

2.4 Limitations of Assessment

The LEUE had several limitations that restricted the human factors experts from performing a full assessment of all aspects of the CAAS crew station. Only the right crew station seat was equipped with functional flight controls. Therefore, all flying was done from the right seat. In real-life missions, pilots would likely alternate flying responsibilities periodically. In addition, the flight controls (i.e., the collective and cyclic) were not representative of the actual CAAS hardware. This limited the ability to evaluate the usability characteristics of the flight controls during the missions.

All four MFDs and the two CDUs were simulated with touch screens controlled by computers outside the BHIVE. A comprehensive usability assessment could not be completed since these components were not production-representative hardware; however, the configuration provided an adequate interface to evaluate SA, workload, and the design of displays.

Both the multi-function control unit (MFCU) and multi-function knob (MFK) were limited in functionality. The limitations of the MFK were not significant; however, the limited functionality of the MFCU was significant and resulted in a very limited amount of data being collected regarding usability.

The tactical data link (TDL) messaging also posed some limitations. Only three types of messages were available for use during the LEUE. These messages consisted of position reports, free-text messages, and observation reports. Also, the TDL system was limited to transmitting capabilities only and did not allow pilots to receive incoming messages. This limitation resulted in lower than normal workload associated with managing communications during operational flights.

Several other limitations existed with the software representation of the CAAS cockpit. Some of the software limitations that impacted this evaluation were the lack of a fully functional flight path stabilization system. The CDUs did not share data as intended, the mission and flight planning pages were not fully developed, and the CDU return button on the flight director overlay was inoperable. These limitations are not uncommon when one is replicating a complex aviation system in a prototype simulator; however, they are worthy of noting because we suspect they had some impact on the results of this evaluation.

The order of the scenarios combined with the method of crew rotation presented a unique limitation for the eye tracker data. Since the BHIVE could only be flown from the right seat, the crews rotated seats for each mission scenario. Since there were three missions, the same three pilots were in the right seat for scenario 1 and scenario 3. These two scenarios were the two visual flight rules (VFR) flights for which eye tracker data were collected. Because of this conflict, eye tracker data for the flying pilot in the right seat were limited to a sample size of three instead of six.

The LEUE was intended to be a limited evaluation of the CAAS design. As such, the evaluation used a limited number of participants and only executed a small number of short operational scenarios.

2.5 Test Schedule and Description of Mission Scenarios

The entire evaluation occurred over a two-week time period in October and November 2004 and consisted of two phases. The first phase of the evaluation was pilot training. This was conducted by members of the AMRDEC SSDD and lasted one week. During this training, pilots received a complete overview of the CAAS and were told of any simulation limitations. The training was conducted with classroom instruction, desktop trainers, and the BHIVE. The second phase of the evaluation was the week of testing. Day 1 consisted of a welcome briefing given by the UH-60M PO and a briefing for the first mission. The second day was the first of three days dedicated to flying mission scenarios and data collection. The last day of the evaluation consisted of a final AAR and briefing.

The trials consisted of three mission scenarios developed by the Directorate of Combat Developments UH-60 user representative from Fort Rucker. The scenarios were developed in accordance with UH-60 tactics, techniques, and procedures. The mission scenarios were VMC flight, IMC flight, and tactical flight. Figures 7 through 9 show the flight plans for each mission scenario.

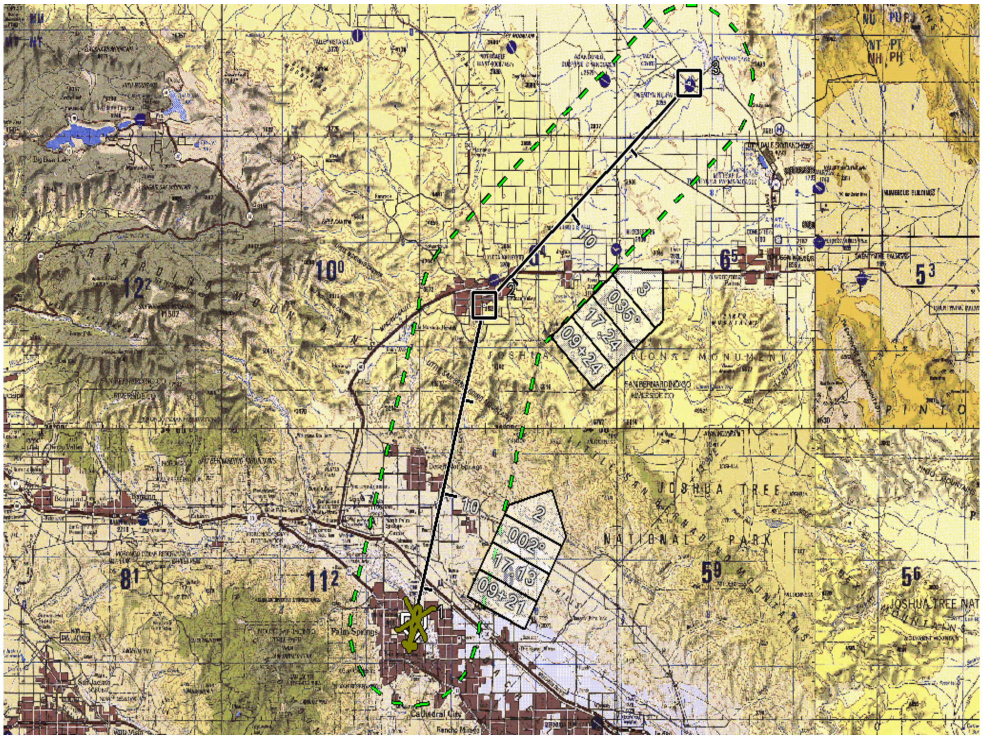

Figure 7. Scenario 1: visual flight rules flight plan.

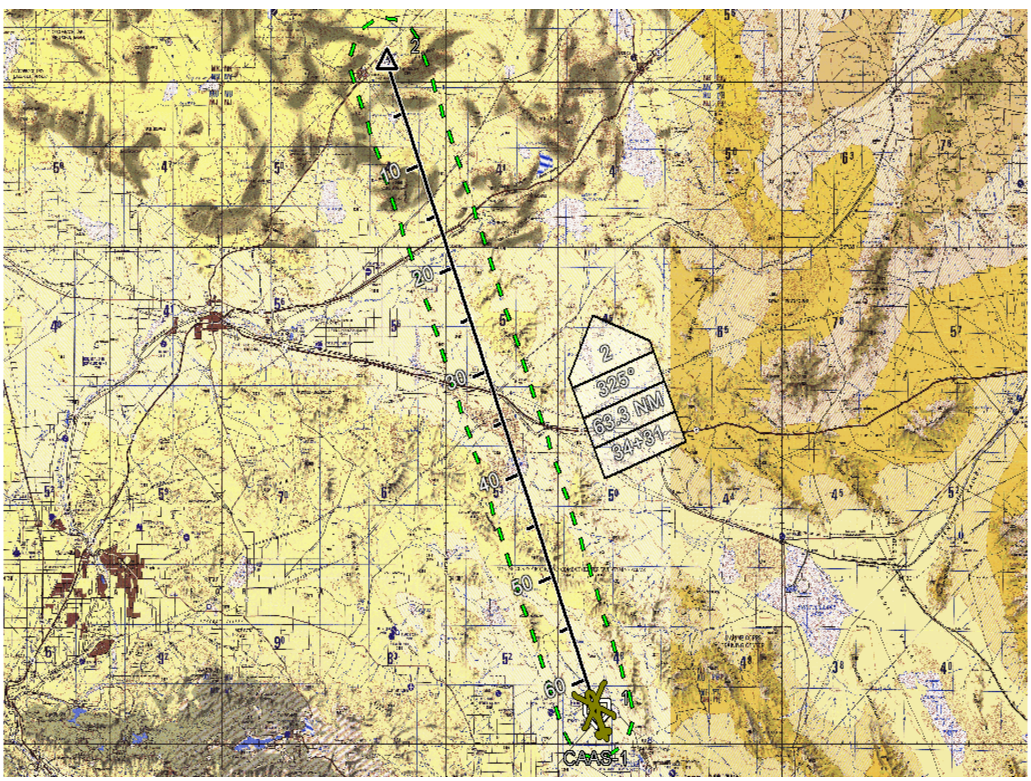

Figure 8. Scenario 2: instrument flight rules flight plan.

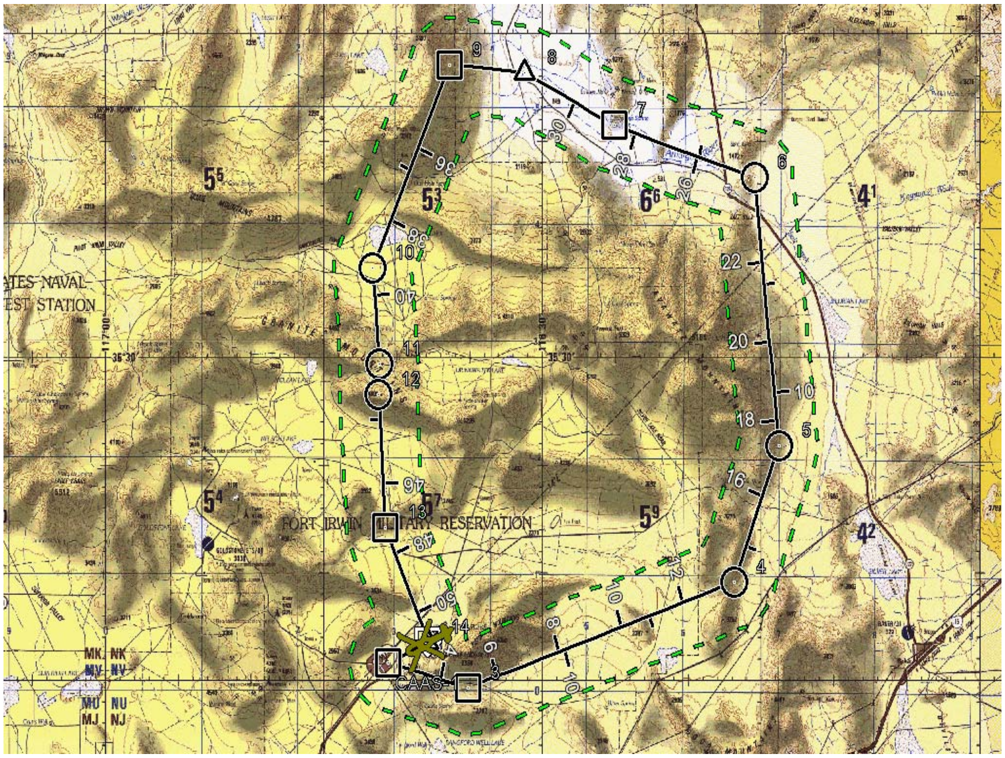

Figure 9. Scenario 3: tactical flight plan.

Three sets of air crews (six pilots) performed each mission scenario. The schedule consisted of all three crews flying the same mission in a single day. This schedule resulted in all three missions being completed in three days for a total of nine flights. The pilots received crew assignments and a mission briefing at the end of each day for the next day's mission, allowing them to plan and rehearse at their discretion in the evening or the next morning.

Each mission concluded with the crews completing the human factors surveys in a nearby office. After all three crews completed the mission and surveys, they participated in a mission debriefing and AAR. At the end of the week, the pilots participated in a final, comprehensive AAR.

3. Results

3.1 Crew Workload

3.1.1 Mean Workload Ratings for ATM Tasks

The mean overall workload rating for all ATM tasks was 3.10. The workload ratings were also looked at individually for each seat since flight controls were only available for the right seat of the BHIVE. The mean workload rating was 3.33 for the left seat and 2.98 for the right seat (see

figure 10). These ratings indicate that the pilots typically had “enough workload capacity for all desirable additional tasks” while performing crew duties from either seating position. The difference in workload ratings between the left and right seats was statistically significant (WSRT, z = -2.201, $p = 0.028$); however, the practical difference is not significant because both ratings are clustered around the “3” on the BWRS.

Two tasks received peak workload ratings that indicated that workload was not tolerable for the task. The mean and peak workload ratings for responding to inadvertent instrument meteorological conditions (IIMC) were 4.33 and 8.00. The mean and peak workload ratings for operating the CDU were 4.19 and 7.00. The mean ratings indicate that the workload required for these tasks resulted in insufficient spare workload capacity for easy attention to additional tasks; however, the peak ratings indicate that there were moments of intolerable workload associated with these tasks. Pilots indicated that they experienced high workload for these tasks because too many steps were required to set critical settings in the CDU. Peak workload is noteworthy because even short periods of intolerable workload can overwhelm the pilots and create the potential for pilot error. Peak workload ratings higher than 7.00 should be identified and resolved through crew station design. Appendix F includes a table of mean workload ratings for all tasks. A set of pilot comments regarding workload is included in appendix G.

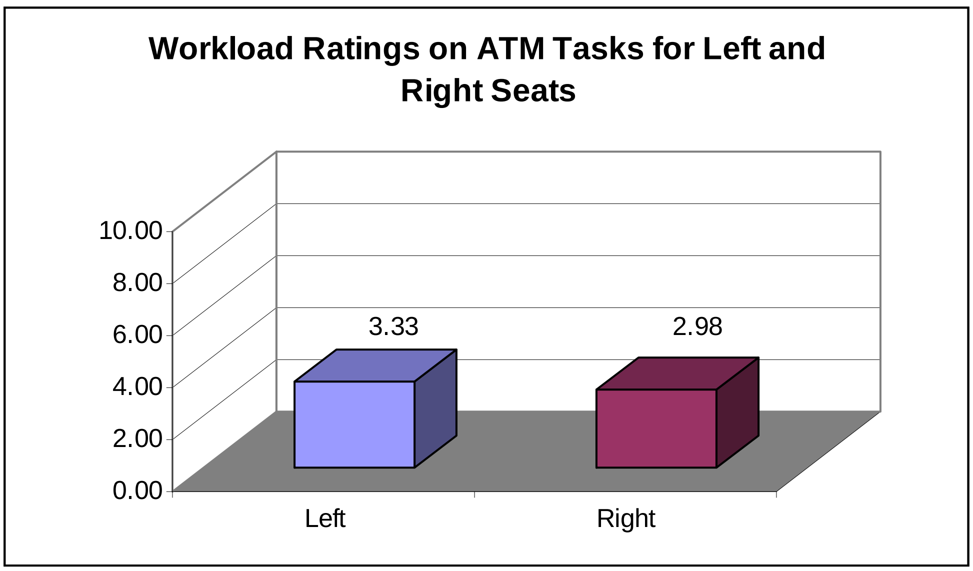

Figure 10. Workload ratings on ATM tasks for left and right seats.

3.1.2 TSC Ratings for Workload and Crew Coordination

The TSC provided an overall mean workload rating of 2.89 for pilots sitting in either crew position—a lower rating than the pilots gave themselves. An overall mean rating of 2.89 also indicates that the pilots typically had “enough workload capacity for all desirable additional tasks”. The TSC also gave individual ratings for pilots in each seat. The workload ratings for the left and right seats were 3.00 and 2.78, respectively. TSC comments indicated that the left seat was assigned higher workload ratings because too many button pushes were required to

perform basic co-pilot functions (e.g., systems check, before take-off check, initiate and "close-out" fuel consumption check, and monitor fuel throughout the mission).

The TSC also rated crew coordination for each mission using a 5-point rating scale. The mean crew coordination rating for all missions was 2.44 (see figure 11). The TSC did not provide comments regarding why he rated crew coordination the way he did.

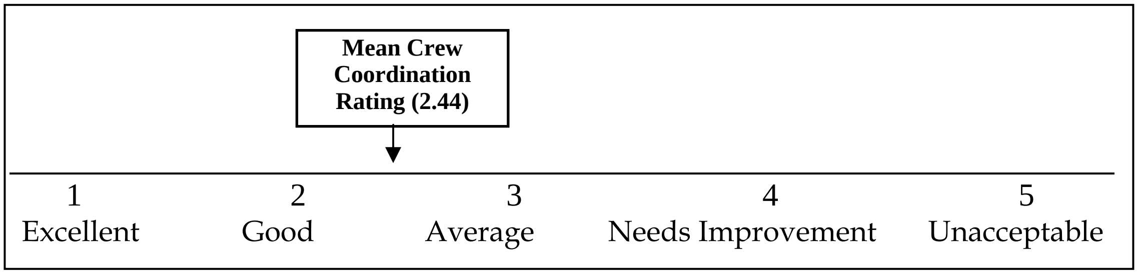

Figure 11. Overall TSC crew coordination ratings.

3.2 Crew Situational Awareness

3.2.1 Situational Awareness Ratings by the Subjects

The overall SART score provided by the pilots was 25.84 for the UH-60M CAAS. This score indicates that the pilots felt they had moderate levels of overall SA during the missions. The SA ratings for the left and right seats were 26.42 and 25.25, respectively (see figure 12). The difference between SA scores for the left and right seats were not statistically significant (WSRT, z = -0.108, $p = 0.914$).

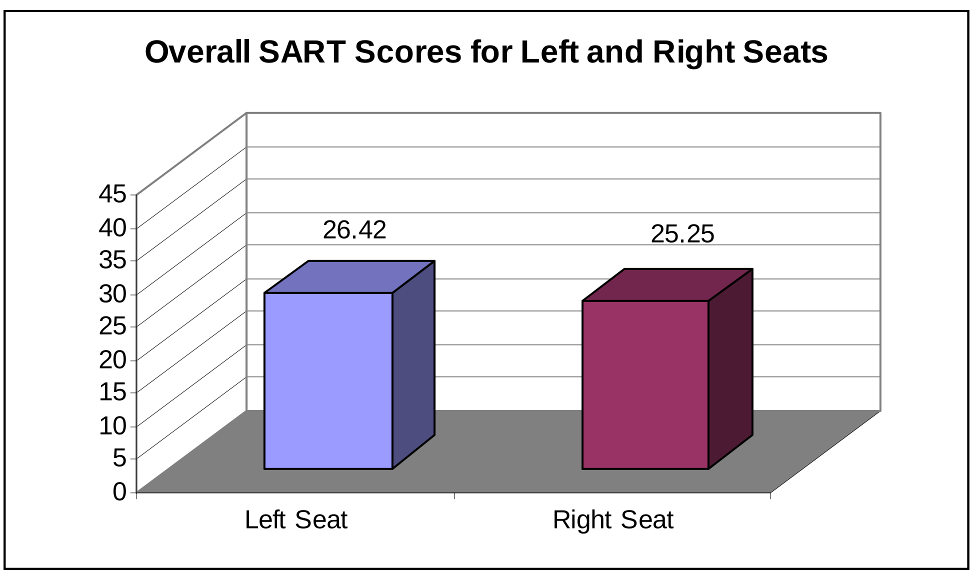

Figure 12. Overall SART scores for left and right seats.

The SA ratings were further analyzed to compare the difference in scores between the VFR and instrument flight rules (IFR) missions. This comparison is particularly important because the flying pilot is completely dependent on the information provided by the aircraft displays during

IFR flight. The mean SART scores for the left seat pilots for VFR and IFR missions were 22.83 and 30.00, respectively. The mean SART scores for the right seat pilots for VFR and IFR missions were 26.17 and 24.33, respectively. Neither of these results was statistically significant; however, the results indicate that the left seat pilots experienced higher SA during IFR flights while the right seat pilot experienced lower SA during IFR flights. Figures 13 and 14 show the comparison of subscale ratings by pilot for VFR and IFR flights. The subscale ratings show that the left seat pilot experienced an increase in supply during IFR missions while the right seat pilot experienced a decrease in supply during IFR missions. Appendix H lists all pilot comments regarding SA.

'Demand' During Missions

VFR: 11.00

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

IFR: 9.33

'Supply' During Missions

VFR: 18.33

Low 1-------4--------7--------10--------13--------16--------19--------21--------24-------28 High

IFR: 24.00

'Understanding' During Missions

VFR: 15.50

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

IFR: 15.33

Figure 13. Comparison of VFR with IFR SA for left seat.

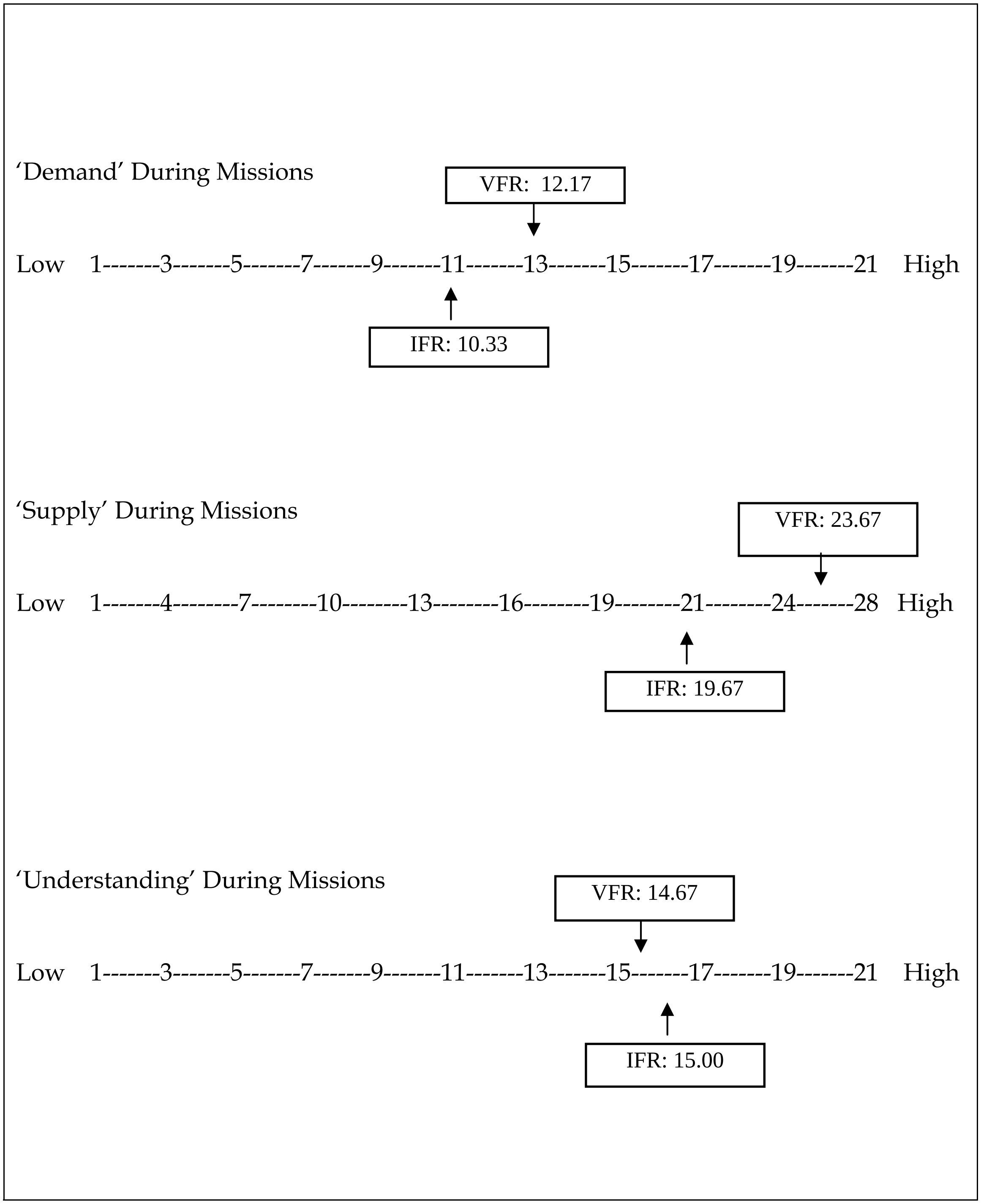

Figure 14. Comparison of VFR with IFR SA for right seat.

3.2.2 TSC Situational Awareness Ratings

The TSC provided an independent assessment of SA based on the scale shown in table 2. The mean TSC SA rating was 1.78. This indicates that the TSC perceived that the crews typically had

adequate levels of SA with some periods of minor variation between perception and reality. A complete set of TSC comments regarding SA is presented in appendix I.

Table 2. TSC situational awareness ratings.

1	Crew was consistently aware of all entities on the battlefield.[1]
2	Crew was aware of the battlefield with minor or insignificant variation between perception and reality.
3	Crew was aware of the battlefield. Variation between reality and perception did not significantly impact mission success.
4	SA needs improvement. Lack of SA had some negative effect on the success of the mission.
5	Lack of SA caused mission failure.

[1]Mean rating 1.78 (SD = 0.67)

3.3 PVI

The pilots completed a comprehensive PVI survey after each mission. This survey allowed the pilots to assign ratings for each question and provide comments on why they rated the question a certain way. This section of the report highlights some of the most common issues that were identified by the pilots, based on the results of the survey or the post-mission AAR. A complete set of PVI results is included in appendix J.

3.3.1 Multi-Function Displays

Pilots were generally comfortable with the symbology used on the MFD pages in the CAAS cockpit; however, they reported several problems with the vertical situation display (VSD), engine instrument caution advisory system (EICAS), and digital map.

Sixty-one percent of the pilot responses indicated that they experienced problems using the VSD during the missions. One design feature that pilots identified as a major safety concern was the angle-of-bank indicator. This indicator is situated on the top of the VSD and displays the angle of aircraft bank when the pilot enters a turn (see figure 15). The design of the angle-of-bank indicator in the CAAS cockpit works differently from angle-of-bank indicators in all other Army aircraft. Even after being trained to use the angle-of-bank indicator and knowing that it worked differently, pilots often increased their angle of bank when they intended to roll out of a turn.

Another issue the pilots identified with the VSD was that there was no fuel indicator on this "page"[4]. Fuel is a critical variable that needs to be monitored constantly during flight. The current procedure in the CAAS cockpit to check the aircraft's fuel level requires several button pushes on the MFD to access the fuel status. The pilots indicated that this procedure was too cumbersome for them to perform a routine task.

The lack of a Kollsman window was also identified as a shortcoming of the CAAS design. A Kollsman window is a display used on other Army aircraft to display the four-digit altimeter

[4]The aircraft's multi-function displays have the flexibility to display multiple "pages." The VSD is one "page" that can be displayed.

setting. The pilots must frequently change the barometric altimeter setting because the barometric pressure changes frequently. The CAAS does not use a Kollsman window. Instead, this information is situated on the CDU. Pilots indicated that the procedure required to check and modify the altimeter setting was workload intensive and they recommended the use of a Kollsman window on the MFD.

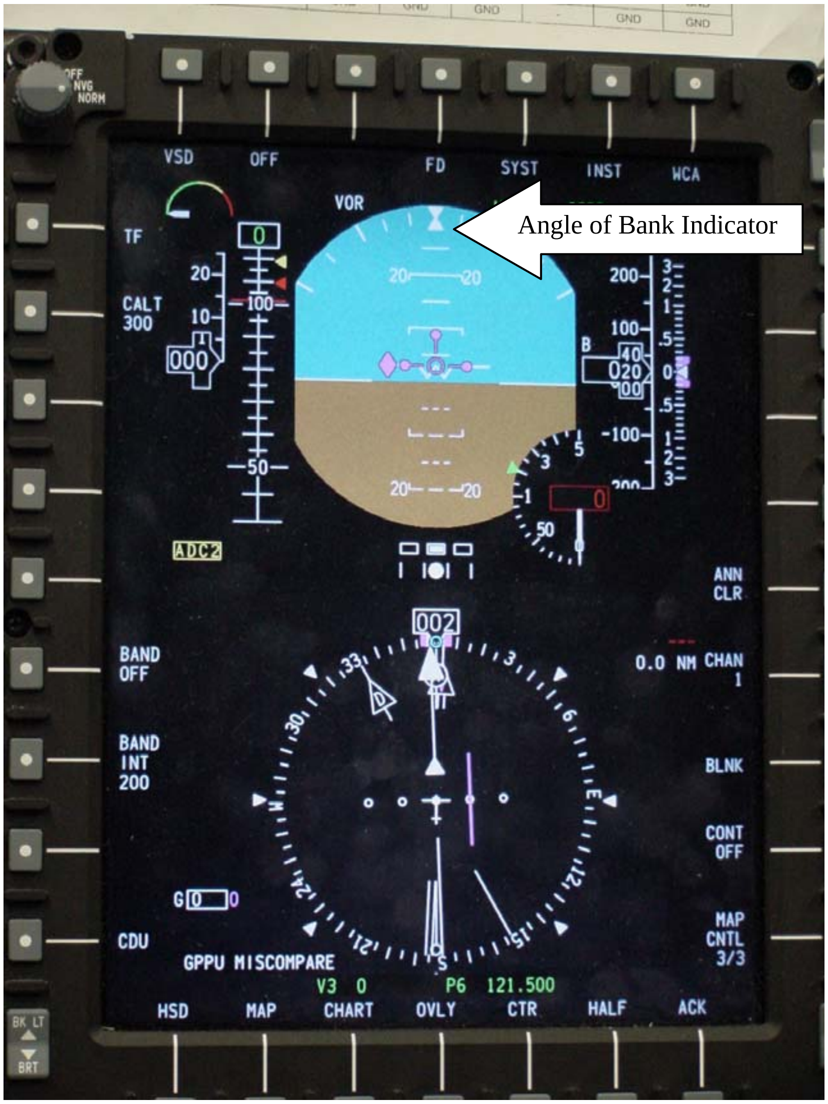

Figure 15. VSD angle of bank indicator.

Seventy-eight percent of the pilot responses indicated that they experienced problems using the EICAS during the missions. The most common complaint by the pilots was that, given the current design, they could not monitor all required instruments and systems simultaneously. Each pilot has two MFDs that can be split to display a total of four different MFD pages. Typically, the flying pilot must monitor the VSD and horizontal situation indicator (HSD) on one MFD. On the other MFD, the pilots usually displayed the digital map and the engine and transmission systems. At this point, all four sections are being occupied and the pilot does not

have the ability to see fuel without additional button pushes on the MFD. The pilots recommended adding fuel to the VSD or incorporating all aircraft systems on a single EICAS page.

Sixty-one percent of the responses reported that the pilots experienced problems using the digital map. The light colors of the HSD, route lines, cursor, and aircraft symbol are very difficult to see when they are overlaid on the light digital map. Pilots recommended changing the color of these features in order to make them more visible on the digital map.

3.3.2 Multi-Function Knob (MFK)

Only 22% of the pilot responses indicated that they experienced problems using the MFK; however, only 11% of the responses reported that pilots preferred using the MFK over manually typing settings into the CDU. Pilots reported that the process of navigating through the CDU in order to activate the function of the MFK was workload intensive. Most pilots indicated that after performing the required steps on the CDU to activate the MFK, they would prefer to continue entering digits in the CDU. The pilots recommended that the MFK be linked to “hot keys” on the MFD overlay pages, which would easily activate the MFK for specific functions with a single button push or that multiple knobs be used—each with its own specific function.

3.3.3 Central Display Unit (CDU)

The pilots did not report many problems setting the initial settings in the CDU; however, they did report problems managing global positioning system/flight plan (GPS/FP) and communication/navigation (COM/NAV) information in the CDU during the missions. The pilots indicated that the CDU was difficult to use because many common functions were too deep in the menu structure. The pilots gave several examples of tasks that were too deep in the CDU, such as changing the altimeter setting, selecting a new heading, and changing air control point (ACP) locations. In most cases, the pilots commented that the menu structure for the CDU was not intuitive and it caused them to forget where certain functions were. We suspect, however, that a large percentage of these problems were caused by the inappropriate or incomplete implementation of the CDU in the BHIVE and that if the pilots were given a production-representative CDU, many of these problems would be eliminated.

3.3.4 Other PVI Issues

- The zoom feature on the digital map was difficult to use.
- The needles on the HSD should be different colors so they are easier to distinguish.
- The heading select marker should have the capability to be selected without engaging the flight director.

- The font size of the letters and numbers on the HSD was too small and difficult to read. In particular, the cardinal directions (i.e., north, south, east, west) should stand out so it is easy to determine the aircraft's general direction at a glance.

3.4 Simulator Sickness

Pilots reported very few simulator sickness symptoms during the LEUE. Most of the symptoms involved slight sweating, general discomfort, fatigue, and mild eyestrain. The overall mean total severity score (post mission) for the pilots was 9.15 (see table 3). The simulator sickness scores were also compared for VMC versus IMC missions. The total severity scores for VMC and IMC missions were 12.15 and 6.23, respectively. These results show a large difference; however, the difference was not statically significant (WSRT, z = -1.753, $p = 0.08$). Overall, the BHIVE posed no problems for simulator sickness and should continue to be very suitable as a simulation environment in the future.

Table 3. Simulator sickness questionnaire ratings.

Condition	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)	SD
Pre-Mission	2.64	3.35	3.87	3.73	4.59
Post Mission	6.36	11.81	3.09	9.15	7.39
VMC	9.54	14.53	4.64	12.15	9.37
IMC	4.77	6.32	4.64	6.23	10.22

SD = standard deviation

3.4.1 Comparison of BHIVE SSQ Scores to Other Helicopter Simulators

To assess whether the SSQ ratings provided by the pilots during the LEUE were similar to or different from ratings obtained in other helicopter simulators, the mean total severity scores for the BHIVE were compared to the mean total severity scores for several other helicopter simulators (AH-64A, S-3H, CH-46E, CH-56D, CH-56F, Sikorsky reconnaissance attack helicopter [RAH]-66 engineering development simulator [EDS], RAH-66 Comanche portable cockpit [CPC], and the BHIVE from the early user demonstration [EUD]) (see table 4). These simulators typically induced low to moderate levels of simulator sickness symptoms in pilots.

Table 4. Comparison of BHIVE SSQ ratings with other helicopter simulators.

Simulator	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
AH-64A*	-----	-----	-----	25.81
SH-3H	14.70	20.00	12.40	18.80
RAH-66 EDS	11.84	14.98	4.54	13.25
CH-53F	7.50	10.50	7.40	10.00
RAH-66 CPC	3.29	12.94	7.89	9.80
UH-60 BHIVE (LEUE)	**6.36**	**11.81**	**3.09**	**9.15**
UH-60M BHIVE (EUD)	13.88	6.89	0	8.50
CH-53D	7.20	7.20	4.00	7.50

CH-46E	5.40	7.80	4.50	7.00

*SSQ subscale data not available.

3.5 Eye Tracker

The importance of collecting eye tracker data was to determine how well the design of the aircraft allowed the flying pilot to remain focused outside the aircraft during VFR flight. During the missions conducted during the LEUE, there were several instances when the pilots momentarily landed to pick up or drop off troops. Eye tracker data collected during these periods of the experiment were eliminated from the analysis of the eye tracker. Scenario 2 was an IFR flight. During IFR flight, pilots remain focused inside the aircraft and flew the aircraft based on the aircraft instruments. Eye tracker data were not collected during scenario 2. Finally, the BHIVE was limited to being flown from the right seat only. In a realistic scenario, pilots would occasionally transfer flight controls so they could safely perform other duties. During the LEUE, this was not possible. This is important to point out because significant differences in eye tracker data are common between the flying and non-flying pilots. In this case, the flying pilot was always in the right seat.

Table 5 shows the percentage of time that the left and right seat pilots were focused on each area of interest defined in the crew station. The "other" category, also defined in the method section of this report, included periods of time when the pilots were focused in an area not defined by an area of interest. Examples include looking down at their kneeboard or glancing across the cockpit to see the other pilot's displays.

Table 5. Summary of eye tracker results for left and right seats.

	Out the Window	**Left MFD**	**Right MFD**	**CDU**	**Other**
Left Seat	26.30%	13.85%	35.68%	7.89%	16.27%
Right Seat	60.86%	8.51%	27.20%	0.05%	3.39%

Figure 16 shows the eye tracker data in a graphical format.

The data indicated that the right seat pilot spent an unusually high percentage of time focused on the right MFD. This anomaly motivated us to further analyze the data to determine the cause of this problem. We determined that a significant difference in results between subjects was the cause of the unusual data. Two of the subjects were Aviation Technical Test Center (ATTC) experimental test pilots. Table 6 shows a comparison of eye tracker results for the ATTC pilots and non-ATTC pilots. The comparison indicates that the ATTC pilots spent a much larger percentage of time focused on the right MFD than the non-ATTC pilots. After consulting with the ATTC pilots and several other SMEs, we concluded that this was caused by the specialized training and experience of experimental test pilots. Experimental test pilots are highly experienced pilots who are trained to perform advanced test flight maneuvers in the aircraft and closely monitor the aircraft systems during these maneuvers.

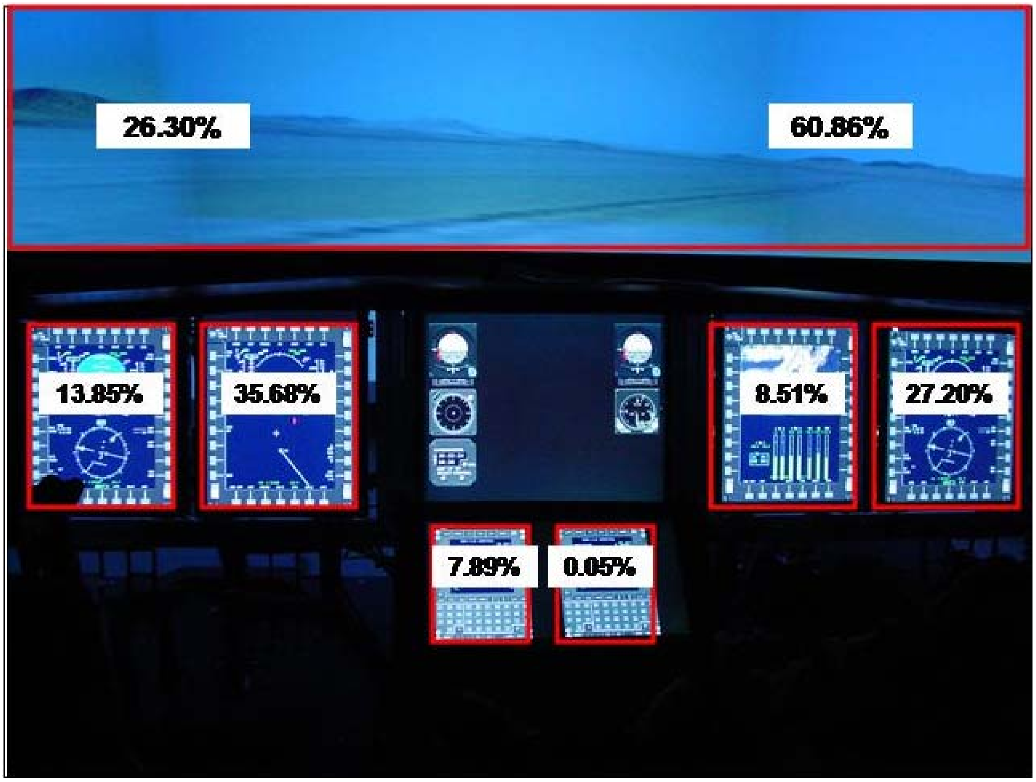

Figure 16. Graphical representation of the eye tracker results.

Table 6. Comparison of eye tracker results from ATTC versus non-ATTC pilots (right seat).

	Out the Window	Left MFD	Right MFD	CDU	Other
ATTC	52.06%	6.34%	38.02%	0.00%	3.59%
Non-ATTC	75.58%	12.14%	9.11%	0.13%	3.05%

3.5.1 Comparison of Eye Tracker Data From Previous UH-60 Assessments

The LEUE was the third of a series of evaluations conducted to evaluate the suitability of the UH-60M crew station. Eye tracker data were also collected during the previous two UH-60 evaluations, the EUD2 and the limited user test (LUT). Table 7 shows a comparison of eye tracker data from each of the three evaluations. Although a comparison of the results of each evaluation is useful, one must be cautious to remember that each set of data was collected in different evaluations that were all conducted differently. For example, the scenarios flown in each evaluation were different, the areas of interest were defined differently in each evaluation, and a different number of participants with different experience levels participated in each evaluation.

Table 7. Comparison of eye tracker results from EUD2, LUT, and LEUE.

	EUD2		LUT		LEUE	
	Flying Pilot	Non-Flying Pilot	Flying Pilot	Non-Flying Pilot	Flying Pilot	Non-Flying Pilot
Outside	69.21%	N/A	85.60%	28.21%	60.86%	26.30%
Inside	30.79%	N/A	14.40%	71.79%	39.14%	73.70%

4. Summary

4.1 Summary of Crew Workload

- Pilots reported a mean workload rating of 3.10. This indicates that there was enough workload capacity for all desirable tasks.
- Three ATM tasks received peak workload ratings of 6. Tasks with a workload rating of 6 indicate that the level of effort required allows little attention to additional tasks. These tasks were maintain air space surveillance, perform instrument maneuvers, and operate the MFDs.
- Two tasks received peak workload ratings of greater than 6. A workload rating higher than 6 indicates that workload was not tolerable for the task. These tasks were respond to inadvertent IMC and operate CDU.
- The TSC rated the average pilot workload at 2.89, indicating the pilots had enough workload capacity for all desirable tasks.

4.2 Summary of Crew Situational Awareness

- Pilots reported a mean SA rating of 25.84, with very little difference between seat position. This indicates that the pilots felt they had moderate levels of SA during missions.
- The flying pilot reported slightly higher SA during the VMC missions, while the non-flying pilot reported having higher SA during IMC missions.
- SA seemed to be influenced by the information displayed on the MFDs. Pilots reported having difficulty determining the status of the aircraft at all times (i.e., monitoring aircraft systems and fuel, reading the compass on the digital map, and determining the direction of aircraft bank using the bank indicator on the VSD).
- The TSC rated crew SA as 1.78. This indicates that the TSC felt the crew was aware of the battlefield and their own ship with minor or insignificant variation between perception and reality.

4.3 PVI

- The pilots did not feel that all required information was displayed on the VSD. Pilots commented that fuel, Nr (rotor revolutions per minute [rpm]), Ng (gas turbine rpm), and turbine gas temperature (TGT) should be located on the VSD. They also requested that the VSD display a Kollsman window and main fuel.

- The roll rate indicator on the VSD indicates the direction of roll opposite from the current UH-60 fleet. This caused disorientation in some of the pilots and they raised this as a safety concern.
- Pilots overwhelmingly agreed that all engine and transmission systems, fuel, and cautions and advisories should be on a single MFD page.
- The pilots indicated that the process for verifying and changing the altimeter setting required too many steps.
- Pilots noted that the contrast between the digital map and the overlay was not adequate, causing difficulty when they read the overlay data.
- The crews indicated that the CDU menu structure was complicated and non-intuitive. They reported that using the CDU required them to be "inside" too much.
- In general, the crews did not benefit from using the MFK. The process for selecting the MFK function was time consuming and was performed on the CDU. Pilots felt more comfortable finishing the process on the CDU rather than switching to the MFK.

4.4 Simulator Sickness

- Pilots reported mild simulator sickness symptoms after flying missions in the BHIVE. However, pilots reported higher severity scores after VMC flight. The severity scores were 6.23 for IMC missions and 12.15 for VMC missions.
- Simulator sickness symptoms did not adversely affect pilot performance.

4.5 Eye Tracker

- The flying pilot typically spent 60.86% of the time fixated OTW, 27.2% fixated on the right MFD, 8.5% on the left MFD, and only 0.05% on the CDU. The remaining time was spent looking at other areas that were not specifically examined during this evaluation (e.g., kneeboard, center console, etc.).
- The non-flying pilot spent 26.3% fixated OTW, 35.68% on the right MFD, 13.8% on the left MFD, and 7.9% on the CDU. The remaining time was spent looking at other areas that were not specifically examined during this evaluation (e.g., kneeboard, center console, etc.).
- A significant difference was noted between OTW percentages for ATTC versus non-ATTC pilots. The average OTW percentage for ATTC pilots was 52.1% and the average OTW percentage for non-ATTC pilots was 75.6%. This significant difference contributed to the fact that ATTC experimental test pilot (XP's) spend more time monitoring the status of aircraft systems during flight, compared to non-ATTC pilots.

5. Recommendations

The following recommendations are made to enhance the overall effectiveness and suitability of the UH-60M CAAS crew station as it continues its development:

- Address and resolve the workload and PVI issues identified during the LEUE.
- Use the Crew Station Working Group, MANPRINT Working Group, and System Safety Working Group to track issues until satisfactorily resolved.
- During future evaluations, use operational pilots as test subjects instead of XPs. XPs have an extraordinary level of expertise that is valuable in the design stage of a program and during crew station working groups; however, their high level of training and experience is not representative of the intended user population, and using them during HFEs can have an adverse impact on workload, SA, and eye tracker results.
- Maximize the amount of "hands-on" training provided to the test participants before future evaluations. Several pilots indicated that they experienced problems retaining the location of functions during the LEUE. This training shortfall may have negatively impacted workload ratings.
- Future work should include a formal operational evaluation in a production representative aircraft or simulator. Because of the limitations associated with the LEUE, such an evaluation is required to accurately determine the workload and SA associated with flying the UH-60M CAAS.
- Continue to assess the crew station during future simulations and tests to evaluate pilot and system performance and assess new functionality that is integrated into the UH-60M design. Data from the workload, SA, and SSQs, plus the data from the eye tracker, should be collected again during future UH-60M crew station evaluations. This procedural continuity will allow direct comparison after further design and development of the UH-60M crew station to check for continued improvements in workload, SA, and PVI.

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Appendix A. Bedford Workload Rating Scale

1. PIN __ __ __ __ __   2. Date (DD/MMM/YY): __ __ / __ __ __ / 0 4

3. Mission ID number ______________________

4. Right Seat _______   Left Seat _______   (Check one)

Workload

5. Rate the workload for the Flight and Mission Tasks you performed during the mission. Use the scale provided on the last page of this questionnaire. Place the workload rating in the blank next to each Flight and Mission Task. If you did not perform a task during the mission that you just completed, place an X in the non-applicable (N/A) column.

Task No.	Flight and Mission Tasks	UH-60M CAAS Workload	N/A
1024	Perform Before Starting Engines through Before Leaving Helicopter Checks		
1026	Maintain Airspace Surveillance		
1028	Perform Hover Power Check		
1032	Perform Radio Communications Procedures		
1034	Perform Ground Taxi		
1038	Perform Hovering Flight		
1040	Perform VMC Takeoff		
1044	Navigate by Pilotage and Dead Reckoning		
1046	Perform Electronically Aided Navigation		
1048	Perform Fuel Management Procedures		
1052	Perform VMC Flight Maneuvers		
1054	Select Landing Zone/Pickup Zone/Holding Area		
1058	Perform VMC Approach		
1070	Perform Emergency Procedures		
1142	Perform Digital Communications		
1164	Perform Instrument Maneuvers		
1169	Perform Flight Director Operations		
1170	Perform Instrument Takeoff		

Task No.	Flight and Mission Tasks (cont’d)	UH-60M CAAS Workload	N/A
1172	Perform Radio Navigation		
1178	Perform Precision Approach		
1182	Perform Unusual Attitude Recovery		
1184	Respond to Inadvertent IMC		
1253	Operate Central Display Unit (CDU)		
1254	Operate Multifunction Display (MFD)		
1260	Operate Digital Map		
2024	Perform Terrain Flight Navigation		
2026	Perform Terrain Flight		
2032	Negotiate Wire Obstacles		

If you gave a workload rating of ‘6’ or higher for any task in the UH-60M CAAS, explain why the workload was high for the task.

____

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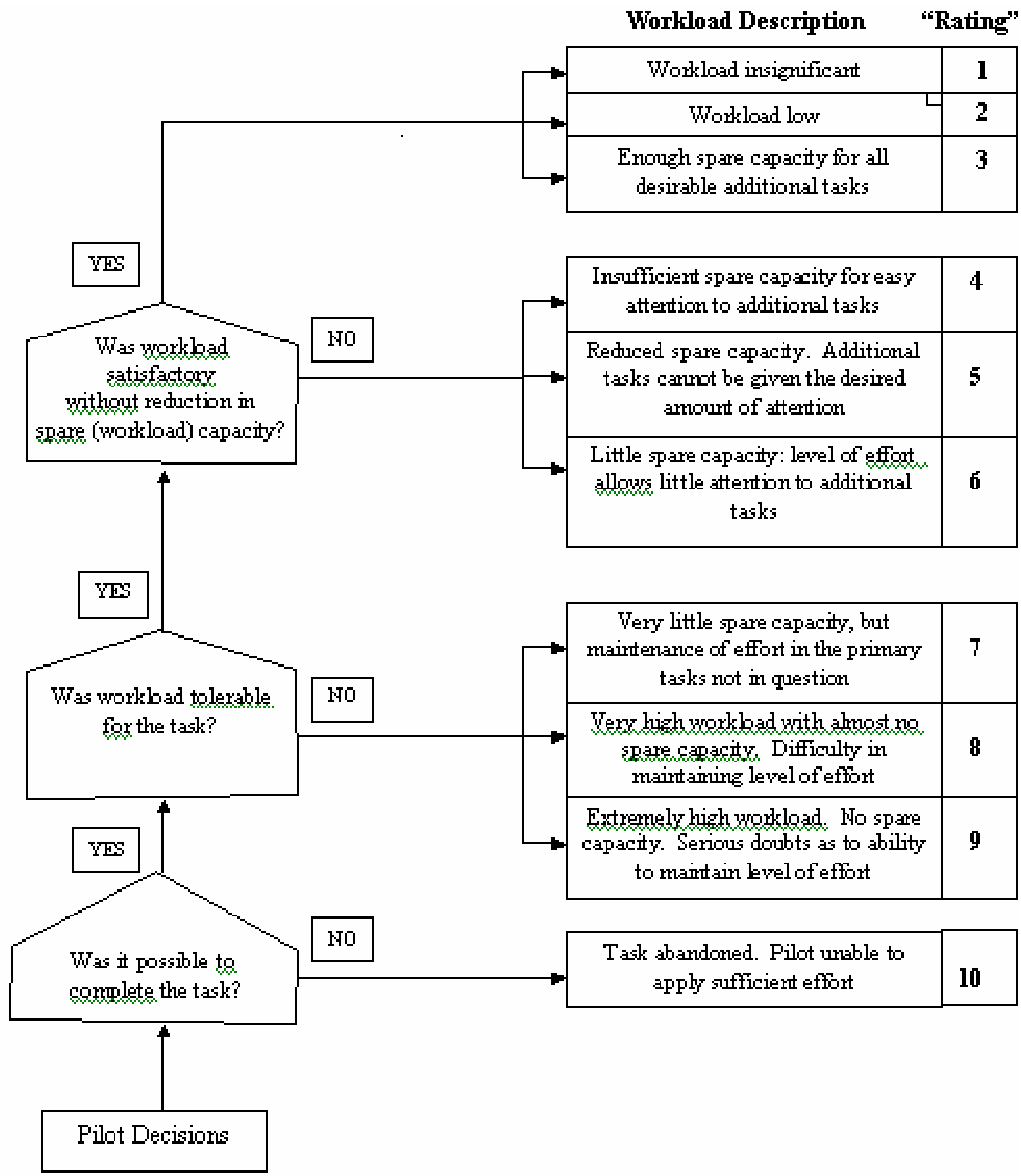
In the mission you just flew, list any flight and/or mission tasks in the UH-60M CAAS that you had to ask your crew member to accomplish because your workload was too high:


Workload Description
"Rating"
Workload insignificant
1
Workload low
2
Enough spare capacity for all desirable additional tasks
3
Insufficient spare capacity for easy attention to additional tasks
4
Reduced spare capacity. Additional tasks cannot be given the desired amount of attention
5
Little spare capacity: level of effort allows little attention to additional tasks
6
Very little spare capacity, but maintenance of effort in the primary tasks not in question
7
Very high workload with almost no spare capacity. Difficulty in maintaining level of effort
8
Extremely high workload. No spare capacity. Serious doubts as to ability to maintain level of effort
9
Task abandoned. Pilot unable to apply sufficient effort
10
YES
Was workload satisfactory without reduction in spare (workload) capacity?
NO
YES
Was workload tolerable for the task?
NO
YES
Was it possible to complete the task?
NO
Pilot Decisions

Appendix B. Situational Awareness Rating Technique

Pin # __ __ __ __ __   Date (DD/MM/YY): __ __/__ __ __/ 04

Mission ID Number: ____________________

Right Seat ________   Left Seat ________   (Check one)

Situation Awareness

SA1. Situation Awareness is defined as “timely knowledge of what is happening as you perform your right or left seat tasks during the mission.”

Situation Awareness Rating Technique (SART)	
DEMAND	
Instability of Situation	Likeliness of situation to change suddenly.
Variability of Situation	Number of variables which require your attention
Complexity of Situation	Degree of complication (number of closely connected parts) of the situation
SUPPLY	
Arousal	Degree to which you are ready for activity; ability to anticipate and keep up with the flow of events
Spare Mental Capacity	Amount of mental ability available to apply to new tasks
Concentration	Degree to which your thoughts are brought to bear on the situation; degree to which you focused on important elements and events
Division of Attention	Ability to divide your attention among several key issues during the mission; ability to concern yourself with many aspects of current and future events simultaneously
UNDERSTANDING	
Information Quantity	Amount of knowledge received and understood
Information Quality	Degree of goodness or value of knowledge communicated
Familiarity	Degree of acquaintance with the situation

For the mission that you just completed in the UH-60M CAAS, rate the level of each component of situation awareness that you had. Circle the appropriate number for each component of situation awareness (e.g., complexity of situation).

DEMAND

Instability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Variability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Complexity of situation:	Low	1---------2---------3---------4---------5---------6---------7	High

SUPPLY

Arousal:	Low	1---------2---------3---------4---------5---------6---------7	High
Spare mental capacity:	Low	1---------2---------3---------4---------5---------6---------7	High
Concentration:	Low	1---------2---------3---------4---------5---------6---------7	High
Division of attention:	Low	1---------2---------3---------4---------5---------6---------7	High

UNDERSTANDING

Information quantity:	Low	1---------2---------3---------4---------5---------6---------7	High
Information quality:	Low	1---------2---------3---------4---------5---------6---------7	High
Familiarity:	Low	1---------2---------3---------4---------5---------6---------7	High

Describe any instances when you feel you had low situational awareness during the mission:

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Appendix C. PVI Questionnaire

1. PIN __ __ __ __ __ 2. Date (DD/MMM/YY): __ __ / __ __ __ / **0 4**

3. Mission ID number ___________________________

4. Right Seat _______ Left Seat _______ (Check one)

PV1. The following table lists the functional components of the UH-60M CAAS crew station. For each functional component, indicate whether or not you experience a problem using the component in a quick and efficient manner during the mission you just completed. Circle "Yes" if you experience one or more problems. Check "No" if you did not experience any problems. Circle "Not Used" if you did not use the functional component during the mission you just completed.

- Multifunction Displays (MFD)
  - o Vertical Situation Display (VSD) Yes ___1___ No ___0___ Not Used ___2___
  - o VSD Hover (VSDH) Yes ___1___ No ___0___ Not Used ___2___
  - o Horizontal Situation Display (HSD) Yes ___1___ No ___0___ Not Used ___2___
  - o HSD Hover (HSDH) Yes ___1___ No ___0___ Not Used ___2___
  - o Digital Map Display (DMS) Yes ___1___ No ___0___ Not Used ___2___
  - o Warning, Caution, Advisory Display (WCA) Yes ___1___ No ___0___ Not Used ___2___
  - o Engine Instrument Caution Advisory System (EICAS) Yes ___1___ No ___0___ Not Used ___2___
  - o Tactical Data Link Messaging (TDL) Yes ___1___ No ___0___ Not Used ___2___
- Control Display Unit (CDU)
  - o Initializing CDU Yes ___1___ No ___0___ Not Used ___2___
  - o Typing TDL Messages on CDU Yes ___1___ No ___0___ Not Used ___2___
  - o Managing GPS / FP Yes ___1___ No ___0___ Not Used ___2___
  - o Managing COM, NAV, IFF (CNI) Yes ___1___ No ___0___ Not Used ___2___
- Multifunction Knob (MFK) Yes ___1___ No ___0___ Not Used ___2___

If you answered "Yes" to any of the questions, please describe a) the problems you experienced, b) how much the problems degraded your performance, and c) any recommendation you have for improving the design of the various functional components.

PV2. Rate the ease of use for the following menu screens on the MFD's (i.e. how quickly could you navigate through the menus and remember the steps required to get to each page).

Vertical Situation Display / Horizontal Situation Display (VSD/HSD) (Circle one)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Digital Map System (DMS) (Circle one)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Control Display Unit (CDU) (Circle one)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Engine Instrument Caution Advisory System (EICAS) (Circle one)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Tactical Data Link Messaging (TDL)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Flight Director (FD)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

If you answered “Somewhat Difficult”, or “Very Difficult” to any of the questions, list the component and why navigation was difficult (e.g., ‘navigating the menu system on the FMS was a slow process due to having to page through several screen displays’).

PV3. Please answer the following questions regarding the Multifunction Control Unit (MFCU):

PV3-1. Did the functionality of the directional control and switches on the MFCU perform the actions you expected?

Yes ___1___ No ___0___ Not Used ___2___

PV3-2. Was the sensitivity of the directional control appropriate?

Yes ___1___ No ___0___ Not Used ___2___

PV3-3. Did you experience abnormal hand discomfort while using the MFCU?

Yes ___1___ No ___0___ Not Used ___2___

If you experienced any problems with the MFCU, please describe the problems in as much detail as you can and make recommendations to correct the problems.

PV4. Did you experience abnormal fatigue or have difficulty using any of the switches on the collective or cyclic grips?

Collective Grip	Yes ____1___	No ____0____
Cyclic Grip	Yes ____1___	No ____0____

If you answered "Yes" for either flight control, please list which flight control and switch(es), and the problems you experienced (e.g., confused two switches due to similar shape, switch too hard to reach).

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PV5. Was there any symbology depicted on the following displays/pages that was difficult to quickly and easily understand, cluttered, or otherwise difficult to use?

Vertical Situation Display (VSD)	Yes ___1___	No ___0___
VSD Hover (VSDH)	Yes ___1___	No ___0___
Horizontal Situation Display (HSD)	Yes ___1___	No ___0___
HSD Hover (HSDH)	Yes ___1___	No ___0___
EICAS	Yes ___1___	No ___0___
Digital Map System (DMS)	Yes ___1___	No ___0___
Tactical Data Link Message (TDL)	Yes ___1___	No ___0___

If you answered “Yes” to any of the questions, please describe a) the display/page, b) the symbology that was difficult to understand, c) how the symbology may have degraded your performance, and d) any recommendation you have for improving the design of the various functional components.

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PV6. For the TDL reports that you sent, how would you rate the ease/difficulty of sending the following reports:

Position Report

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Free Text Message

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Observation Report

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

If you answered “Somewhat Difficult”, or “Very Difficult”, please indicate which type of message you sent, the exact difficulties you encountered, and any recommendations to alleviate the problem.

PV7. How would you rate your ability to detect the following occurrences based on the characteristics of the flight displays?

Incoming TDL Message (MFD)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Caution / Advisory (MFD)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Warning (Master Warning Panel)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Entry into Operational Limits (per Chp 5)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Low Fuel (MFD)

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

If you answered “Somewhat Difficult”, or “Very Difficult”, please indicate which annunciation you had difficulty detecting, why you may have had difficulty detecting it, and any recommendations to make the annunciation more easily detectable.

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Appendix D. Simulator Sickness Questionnaire

1. PIN #: __ __ __ __ __

2. Date (DD/MMM/YY): __ __ - __ __ __ - **04**

3. Mission ID Number: ________

4. Seat you will fly from: Right Seat _______ Left Seat _______ (Check one)

5. Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

Symptom	0	1	2	3
a. General discomfort	None	Slight	Moderate	Severe
b. Fatigue	None	Slight	Moderate	Severe
c. Headache	None	Slight	Moderate	Severe
d. Eyestrain	None	Slight	Moderate	Severe
e. Difficulty focusing	None	Slight	Moderate	Severe
f. Increased salivation	None	Slight	Moderate	Severe
g. Sweating	None	Slight	Moderate	Severe
h. Nausea	None	Slight	Moderate	Severe
i. Difficulty concentrating	None	Slight	Moderate	Severe
j. Fullness of head	None	Slight	Moderate	Severe
k. Blurred vision	None	Slight	Moderate	Severe
l. Dizzy (eyes open)	None	Slight	Moderate	Severe
m. Dizzy (eyes closed)	None	Slight	Moderate	Severe
n. Vertigo*	None	Slight	Moderate	Severe
o. Stomach awareness**	None	Slight	Moderate	Severe
p. Burping	None	Slight	Moderate	Severe

* Vertigo is a loss of orientation with respect to vertical upright.
** Stomach awareness is a feeling of discomfort just short of nausea.

6. Are you in your usual state of health and fitness? **YES** **NO**

7a. Have you been ill in the past week? **YES** **NO**
b. If yes, are you fully recovered? **YES** **NO** **N/A**

1. PIN #: __ __ __ __ __   2. Date (DD/MMM/YY): __ __ - __ __ __ - **04**

3. Mission ID Number: ____________________________________

4. Seat you flew from: Right Seat _______ Left Seat _______ (Check one)

5. Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

Symptom	0	1	2	3
a. General discomfort	None	Slight	Moderate	Severe
b. Fatigue	None	Slight	Moderate	Severe
c. Headache	None	Slight	Moderate	Severe
d. Eyestrain	None	Slight	Moderate	Severe
e. Difficulty focusing	None	Slight	Moderate	Severe
f. Increased salivation	None	Slight	Moderate	Severe
g. Sweating	None	Slight	Moderate	Severe
h. Nausea	None	Slight	Moderate	Severe
i. Difficulty concentrating	None	Slight	Moderate	Severe
j. Fullness of head	None	Slight	Moderate	Severe
k. Blurred vision	None	Slight	Moderate	Severe
l. Dizzy (eyes open)	None	Slight	Moderate	Severe
m. Dizzy (eyes closed)	None	Slight	Moderate	Severe
n. Vertigo*	None	Slight	Moderate	Severe
o. Stomach awareness**	None	Slight	Moderate	Severe
p. Burping	None	Slight	Moderate	Severe

* Vertigo is a loss of orientation with respect to vertical upright.
** Stomach awareness is a feeling of discomfort just short of nausea.

Appendix E. Tactical Steering Committee Questionnaire

Pin: ________________

Mission Trial _______________ Date (DD/MMM/YY): __ __ / __ __ __ / **0 4**

TSCWL1. Place the workload rating in the blank next to each crewmember using the rating scale on the next page.

Crew members	Overall Workload Rating For This Mission
Left Seat	
Right Seat	

If you assigned a workload rating of '6' or higher for either crewmember, explain why:

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TSCWL2. Rate the effectiveness of aircrew coordination as defined by the USAAVNC Aircrew Coordination ETP and TC 1-210.

1	2	3	4	5
Excellent	Good	Average	Needs Improvement	Unacceptable

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PIN __ __ __ __ __ Date (DD/MMM/YY): __ __/ __ __ __/ 0 4

Mission ID number ________________________

TSC SITUATION AWARENESS RATING SCALE

UH-60M CAAS	Circle One
Crew was consistently aware of all entities on the battlefield as well as the status of their aircraft	1
Crew was aware of the battlefield and their own ship with minor or insignificant variation between perception and reality.	2
Crew was aware of the battlefield and their own ship. Variation between reality and perception did not significantly impact mission success.	3
SA needs improvement. Lack of SA had some negative effect on the success of the mission.	4
Lack of SA caused mission failure.	5

Describe any problems that aircrews had with situation awareness.

PIN __ __ __ __ __   Date (DD/MMM/YY): __ __ / __ __ __ / 0 4

Mission ID number ____________________________

TSC MISSION SUCCESS QUESTIONNAIRE

TSC MS1. Did the UH-60M CAAS crew complete their mission objectives?

Yes ___1__   No ___0__

If no, why weren't the mission objectives completed?

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TSC MS2. Was the mission successful?

Yes ___1__   No ___0__

If no, what caused the mission to fail?

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Appendix F. Mean Workload Ratings for All ATM Tasks

ATM Task Description		1	2	3	4	5	6	AVG	Peak
1024	Perform Before Starting Engines through Before Leaving Helicopter Checks	2.00		2.00	2.67	3.00	3.00	2.53	3
1026	Maintain Airspace Surveillance	5.50	5.00	2.67	3.00	2.00	2.00	3.36	6
1028	Perform Hover Power Check	2.33	4.67	1.50	1.33	2.67	2.00	2.42	5
1032	Perform Radio Communications Procedures	3.33	2.67	2.67	1.67	3.00	2.67	2.67	5
1034	Perform Ground Taxi	2.00	2.50	1.00	1.50		2.00	1.80	3
1038	Perform Hovering Flight	3.00	2.50	2.00	2.00	2.00	2.50	2.33	4
1040	Perform VMC Takeoff	4.00	2.50	2.00	2.50		2.50	2.70	4
1044	Navigate by Pilotage and Dead Reckoning	2.50	3.33	2.50	2.67		4.00	3.00	4
1046	Perform Electronically Aided Navigation	3.33	4.00	2.50	3.00	3.33	3.33	3.25	5
1048	Perform Fuel Management Procedures	4.67	4.33	2.50	2.67	2.00	3.00	3.19	5
1052	Perform VMC Flight Maneuvers		4.50		3.00		2.50	3.33	5
1054	Select Landing Zone/Pickup Zone/Holding Area	2.50	2.50	1.00	2.50		4.00	2.50	4
1058	Perform VMC Approach		3.00		2.00		2.00	2.33	4
1070	Perform Emergency Procedures				3.00	3.00	2.00	2.67	3
1142	Perform Digital Communications	3.00		5.00		5.00		4.33	5
1164	Perform Instrument Maneuvers	4.50	4.50	3.00	2.50	3.00	4.00	3.58	6
1169	Perform Flight Director Operations		4.33	3.00	2.67	3.33	4.00	3.47	5
1170	Perform Instrument Takeoff	2.00		3.00	2.00	2.00		2.25	3
1172	Perform Radio Navigation	3.67	4.00	3.00	2.67	3.00	3.00	3.22	5
1178	Perform Precision Approach	3.00	4.00	3.00	2.00	4.00	3.00	3.17	4
1182	Perform Unusual Attitude Recovery				3.00			3.00	3
1184	Respond to Inadvertent IMC	8.00	5.00	4.00	3.00	2.00	4.00	4.33	8
1253	Operate Central Display Unit (CDU)	6.67	5.67	2.67	3.67	3.50	3.00	4.19	7
1254	Operate Multifunction Display (MFD)	5.00	4.67	3.00	3.33	3.00	4.00	3.83	6
1260	Operate Digital Map	4.00	4.33	2.67	3.33	3.00	4.00	3.56	5
2024	Perform Terrain Flight Navigation	3.00	3.00	2.00	4.00	2.00		2.80	4
2026	Perform Terrain Flight		3.00		4.00		4.00	3.67	4
2032	Negotiate Wire Obstacles	2.00	2.50		3.00		2.00	2.38	3

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Appendix G. Pilot Workload Comments

If you gave a workload rating of 6 or higher on the UH-60M CAAS, explain why the workload was high for the task.

Task (1026)

- The heads-down nature of the CDU brought the flying pilot inside for too long.
- Resetting flight director commands was too heads-down.

Task (1028)

- Had to bring up instrument page and increase scan to verify all engine parameters were okay. Would like to see more on the power pod.
- Had to cycle through instrument pages to get all the required aircraft information.
- Cockpit is too heads-down. Need fuel, Kollsman window, Nr, TGT, and Ng pop-ups on PFD. Need easy way of changing flight director settings. Need ONE all-inclusive EICAS page.

Task (1032)

- Collective radio control was easy to use. Would like to be able to see what radio the other pilot had selected on the MFD.
- Would like to see other pilots selected radio on MFD.

Task (1044)

- Heads-down nature of cockpit brings you inside too much.
- Heads-down cockpit. No heading bug without flight director.

Task (1046)

- Had to scan other pilots MFD for exact position since my map display didn't have an aircraft symbol.
- Moving map is good. Would like aircraft symbol on all digmap pages. Recommend making the ACP, ADF, VOR, and TACAN needles different colors.
- Need easier, heads-up way of adjusting heading, course, and flight director settings.

Task (1048)

- Had to pull up a fuel display while on controls to monitor fuel.
- Need fuel display on PFD.
- No fuel on PFD.

Task (1052)

- Angle of bank pointer moved in counter intuitive direction causing me to steepen turns instead of rolling wings level.
- Heads-down cockpit. No heading bug without flight director.

Task (1058)

- If heavy or coming in “Hot”, Ng and TGT pop-ups on PFD would be helpful.

Task (1142)

- Digital communications took from 11 to 20+ button pushes to send a simple position report. At least 30 seconds inside the cockpit to perform this task.

Task (1164)

- The heads-down nature of the heading and course bugs made setting up the cockpit for the flying pilot difficult.
- High workload for basic NAV caused by cumbersome input devices.
- Need easier way of changing FD settings.

Task (1169)

- The heads-down nature of the heading and course bugs made setting up the cockpit for the flying pilot difficult.
- Need easier way of changing FD settings.

Task (1172)

- Changing course-to was heads-down.

Task (1176)

- Changing course-to was heads-down.

Task (1184)

- This task-saturated event is turned into a task-unmanageable event by the introduction of current CAAS. What was my altimeter setting? We leveled off and still did not know. I did not have time to tune a VOR prior to level off, therefore giving a position report was somewhat inaccurate (the map was no help). Putting up a heading bug took too long because it was not on a main page. Setting altimeter was too time consuming and difficult.
- Finding proper overlay to quickly bring up bearing pointer and CDI is difficult.

Task (1253)

- Three to four button pushes to just begin to enter altimeter setting. Entering data with the MKF was cumbersome and time consuming when used with the CDU. Too many button pushes to enter a course for the CDI.
- Menu structure has too many layers, information is difficult to find, too much heads-down.
- Was too difficult to accomplish the basic tasks such as entering altimeter, course set display, and heading settings while flying instruments.
- Menu structure non-intuitive and too deep. Should be able to set-up FD commands (altitude, airspeed, heading) without engaging the flight director. Overlay and zoom menu structure confusing. Bezel keys should indicate where I’ll go if I select the button, not where I’m at now.
- Data entry takes way too long. Need more hotkeys. Primary finction are buried too deep in pages.
- Too many sub-menus. Menu structure not intuitive.

Task (1254)

- Absolutely must be an altimeter/Kollsman window on the MFD. Absolutely must be able to put any screen in any position on the MFD's.
- PFD doesn't display enough information, requiring frequent page switching.
- Not enough basic/critical data displayed on MFD. (e.g., altimeter setting, fuel) Need more hot keys and top-level functions. Relable MFD key to show the next function, not the current function. Add knobs and buttons to compliment MFD. It would have helped on this mission.
- Setting up split screen is non-intuitive. Too many flight director and overlay pages.

Task (1260)
- All digital map displays need aircraft symbol.
- Operating the flight director required too many button pushes. For example, selecting heading required selecting FD from the MFD, then HDG on the left sike LSK, then FD on CDU, either entering the heading manually or using the MFK (which I did not use). This is way too much workload to get a heading indication.
- Set-up difficult.

Additional Comments

- Operating the flight director required too many button pushes. For example, selecting heading required selecting FD from the MFD, then HDG on the left sike LSK, then FD on CDU, either entering the heading manually or using the MFK (which I did not use). This is way too much workload to get a heading indication.
- Even though I didn't have any workload ratings higher than 6, when trying to perform multiple tasks that score 3 or 4, the workload becomes high. There are cases where selecting the correct overlay on the HSD was difficult. Each pilot may have a difficult time determining what the other pilot has displayed in terms of bearing pointers and CDI (the NAV source, such as CDI-VOR, CDI-ADF). This may show conflicting information between Left and Right pilot displays and could lead to disorientation.
- Overall, workload is too high in setting up, using, and changing MFDs, flight director modes, etc. Overflying an exact waypoint is difficult because the flying pilot cannot have a PFD, digmap, and systems displayed simultaneously. The CDI and bearing pointer auto turn prior to ACP and did not see a way to select manual feature in this simulation.
- If the MFDs were designed better OR there was an auto paging when needed (e.g., low oil pressure, etc) then that would be no factor. As it is, you must monitor to ensure you don't exceed Ng, etc.

In the mission you flew, list any tasks in the UH-60M CAAS that you had to ask your crew member to accomplish because your workload was too high.
- The pilot on-the-controls made some radio calls to reduce pilot not-on-the-controls workload. For this first flight, the pilot-not-on-the-controls could perform all functions but with increased difficulty.
- Had to have the other pilot adjust my heading and course bugs. Too heads-down for the flying pilot to do.
- Set altimeter setting.

- None, however I did have to ask my crewmember about how to perform a task (i.e. pull up the CDU window for altimeter setting.
- I did not feel comfortable leaving the controls to search for and fumble through pages of menus to perform basic tasks which I listed before.
- I did not ask my crewmember to do any specific task because of workload. He did change heading for flight director and airspeed for the flight director so I could get flight director indications.
- Set altimeter, time to next ACP/CP, landing direction into LZ/PZ.
- Everything that didn't include moving the flight controls. For example, changing altimeter setting, flight director settings, heading bug, CDI, etc.
- The pilot on-the-controls has to set his own airspeed bug because I was inside trying to figure out whether or not I had the VOR up correctly.
- Describing upcoming waypoints, since I had my MFDs configured to fly and monitor systems.

If you feel the addition of a 5th MFD would have helped reduce workload, explain.

- On this flight a 5th MFD would have reduced pilot workload. Fuel and instrumentation could have been displayed on the 5th MFD allowing for less page changes and lending more space on the primary MFD's for a flight data oriented page. Alternatives would be to add total fuel and fuel burn to the systems page and also allow the systems page to be viewed in any position. Allow for a Kollsman window to be displayed somewhere on the MFD's. If these changes cannot be made, additional display space is required.
- Yes, with a 5th MFD, fuel, altimeter setting, engine and transmission instruments, map, and PFD could be displayed simultaneously.
- Here it would have allowed me to have system instruments and fuel status displayed. I would not have to switch back from map to instruments to fuel.
- I don't think it is necessary if the 4 MFD's we have are well designed.
- Yes. Allow any function to be displayed in any position. Remove torque from EICAS and insert fuel gauges or strips. Create more space on MFD's or CDU for hot keys. Put a Kollsman window in the system on MFD. If not, yes, we need more display space.
- Yes, could have better monitored aircraft systems. However, I'd rather see a redesigned PFD with fuel, Kollsman window, Ng; and an EICAS that shows engine instrument, caution/advisory, and fuel on one page.
- Yes. Provided more space for hot kays. Provided system and fuel indication or other combinations to be displayed at all times because the system is too difficult to ma ipulate under high stress situations. Therefore, buy not having to select different pages in the current software you decrease workload with a 5th MFD.
- Not if its more of the same. Need redesigned PFD and EICAS.

Appendix H. Pilot SA Comments

Describe any instances when you feel you had low situation awareness during the mission.

- At one point, inside the aircraft too long accessing course and may have made contact with the ground!
- At a quick glance, I reported altitude as 6000 feet when we were actually at 600 feet. The more experienced pilot recognized the error and corrected me. Recommend 1st digit be larger than the rest. Currently the 1st and 2nd digits are larger than the rest.
- I couldn't display all the information I wanted to see simultaneously. I had the inboard MFD split-screen with the map on top and instruments on bottom. As such, I could not get the airplane symbol on the top display and had to toggle the bottom half between systems and fuel.
- When we were given a new altimeter setting, my copilot had to come inside just to see if it was the same as the last setting.
- Could not set heading bug to next course leg without engaging flight director.
- Copilot mis-interpreted altitude as 6000 feet when it was 600 feet.
- When using the digital map, the aircraft symbol would frequently "get lost" in the background. The current course leg would partially "get lost" as well. This is probably due mainly to lack of contrast between the symbols and the map itself. A change in size, color, or shading may help.
- The time I felt low SA was during radio calls and not being real sure about how I would manually switch radio frequencies if they were not in presets.
- Had low SA of my current status due to the inability to pull up engine instruments, caution/advisory, and fuel simultaneously.
- On takeoff, the right side pilot had selected CDI-ACP and I had CDI-VOR. We had different indications, obviously. The problem was that I cannot tell what he had selected from cross-cockpit, causing some confusion about what is displayed and exactly where we were navigating to.
- Outbound on a VOR radial (the 217 radial at Bike Lake) the needle (CDI) indicated reverse sensing. It should be directional.
- Had difficulty sensing a bank on the VSD. Usually corrected to the wrong side.
- Difficult for me to know what information the lollipops were giving me on the VSD. I asked numerous times to the copilot about what indication that symbol was giving me (i.e., heading, course, etc.).
- Landing direction and spot at PZ not coordinated well.
- Wasn't comfortable with the state of my own aircraft. Need an all inclusive EICAS page.
- When approaching an ACP, the CDI bearing pointers auto change prior to overflight. (This is probably selectable in the real CAAS) The flying pilot is unable to have digital map with overlay AND still have the primary flight display (PFD) while monitoring systems. So overflight of the actual, exact point that defines each ACP is difficult.

- When asked to tune up the VOR, but did not get the VOR BRG pointer. But did get the CDI – I did not know if CDI indication were good or not. (No NAV flag!)
- When flying along and spotted the enemy vehicles, I did not know how to store that GPS coordinate in a quick fashion to report later.

If you feel the addition of a 5th MFD would have helped increase situation awareness, explain.

- On this flight, 4 MFD's lended itself more suitable than 5. My adaptation to the flight deck configuration has helped in the manipulation of seeming awkward controls.
- 5th MFD not needed.
- I'd rather see a Kollsman window and fuel display on 4 MFD's. Additionally, need a quick way of setting heading, course, altitude, airspeed, etc without going heads-down to the CDU. If the MFD displays cannot be modified then a 5th MFD is definitely required. Need to be able to display bug (i.e. heading, CDI, etc) without engaging the flight director.
- I don't think so.
- Not during this mission.
- Yes, display fuel would have helped. Altimeter setting on a 5th display would help. Otherwise, design these issues into the 4 MFD configuration.
- I would rather see a well design PFD with fuel, Kollsman window, and NR on the PFD and a redesigned EICAS with engine instruments, caution/advisory, and fuel on one page. If the pages can't be redesigned, then a 5th MFD will be required.
- Yes. To display instruments and fuel or to display fuel and WCA a 5th MFD is required. We must have more space unless we fix the issues with the 4 MFD configuration. Even "more of the same" is still displaying more readily and immediate available information. A 5th display will reduce pilot workload with this software.
- Personal opinion – Fix the data input issues, safety concerns, and data interpretation issues that we have discussed. Then talk about using 4 MFD's. In actuality, this system is not safe as is.
- Not if just more of the same. We need a redesigned PFD and EICAS.
- Today with a 5th MFD I would have displayed instruments! However, I feel the one page redesigned Engine/Systems MFD page would be just as useful (i.e, ALL stsrems & fuel on one single page. If that were the way CAAS was – I could do with 4 MFD's.

Appendix I. TSC Comments

TSC Workload Comments:

- Several button pushes were required to perform basic copilot functions (e.g. systems check, before take-off check, initiate and close-out fuel consumption check, and monitor fuel throughout the mission.

TSC SA Comments:

- Copilot had difficulty recalling altimeter setting changes (non-intuitive).
- Pilot misinterpreted turn indicator to make course corrections. Caused by non-intuitive turn indications.
- Copilot management of flight plan was not implemented to it's fullest capability. Didn't use the course deviation indicator to track to the ACP.
- Pilot on-the-controls had variations in altitude and airspeed greater than ATM standard.
- Crew did not have full CDU functionality to capture airspeed, altitude, and course guidance information (i.e., did not use CDU to capture desired airspeed and altitude to receive queues for airspeed and altitude).
- Pilot on-the-controls had difficulty interpreting course guidance information on the VSD attitude indicator. The aviator commented the display was too prominent (e.g., bright-pink).
- JVMF position reporting didn't allow crew to execute the briefed mission. Could not send position report from MFD. Had to develop work around to use the MFCU.
- IIMC aviator distracted through flight plan model errors that caused over controlling. Eventually the aviator was able to establish level flight.
- Simulation device error caused aviator workload to increase. VOR receiver was not operational. Aviator had loss of situation awareness and unable to recover from inadvertent IMC.

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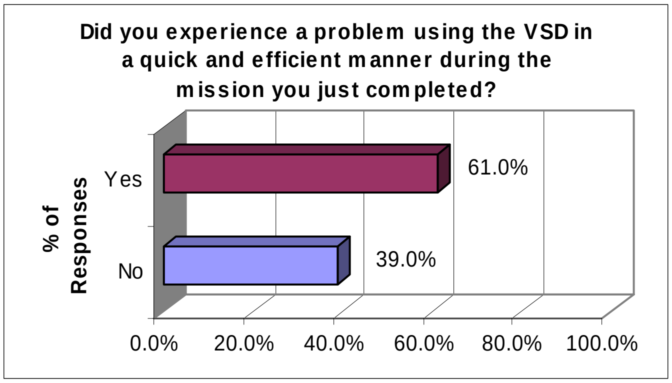
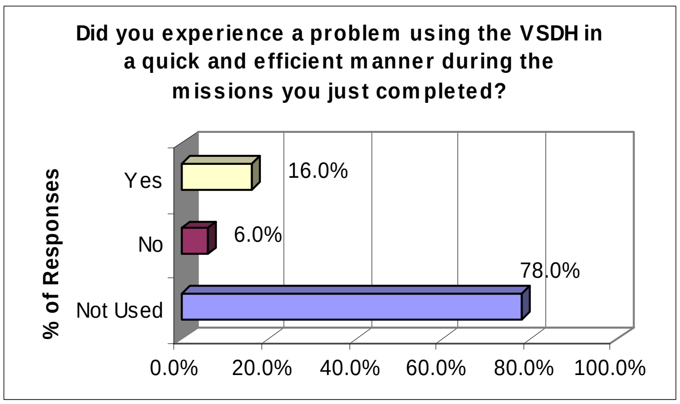
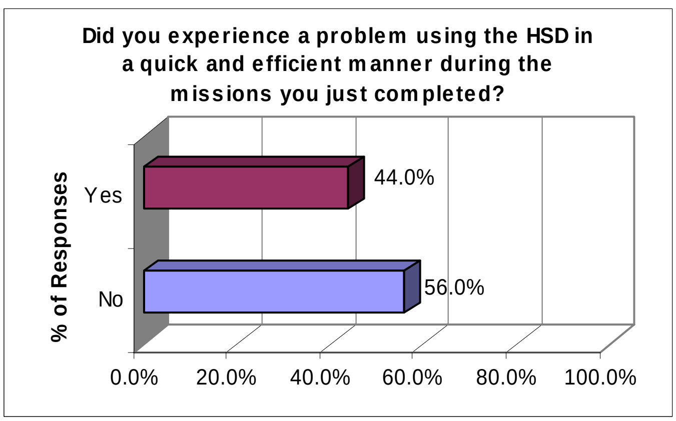
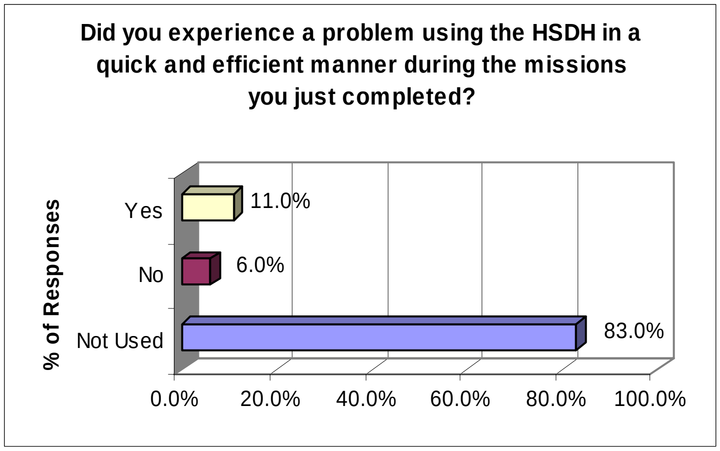
Appendix J. Pilot PVI Summary and Comments

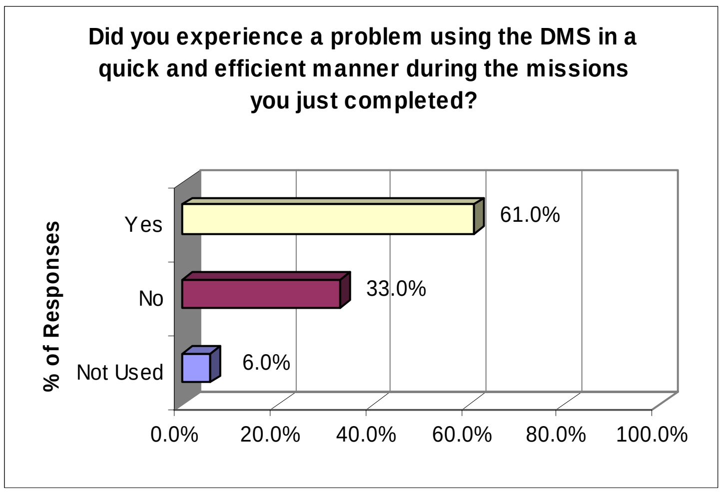
PV1 Comments

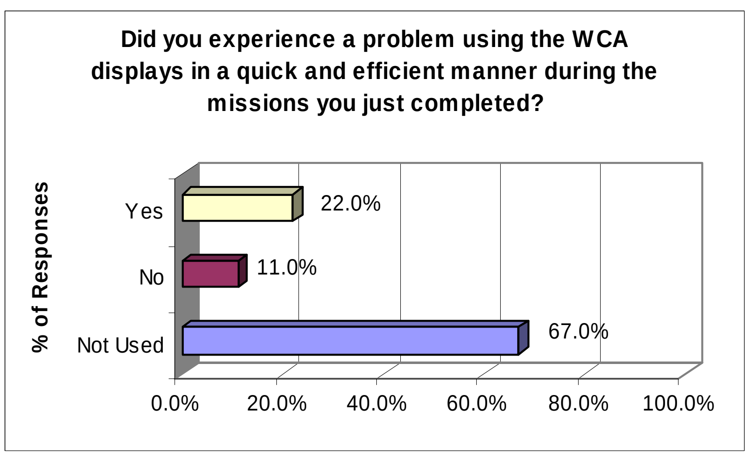


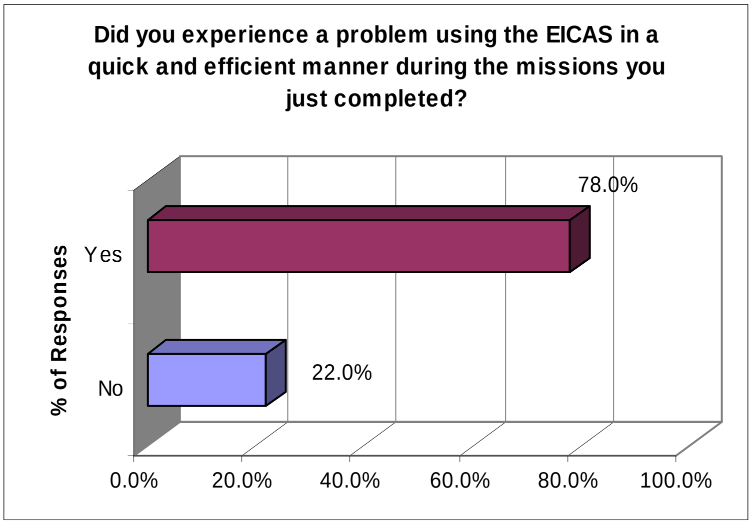


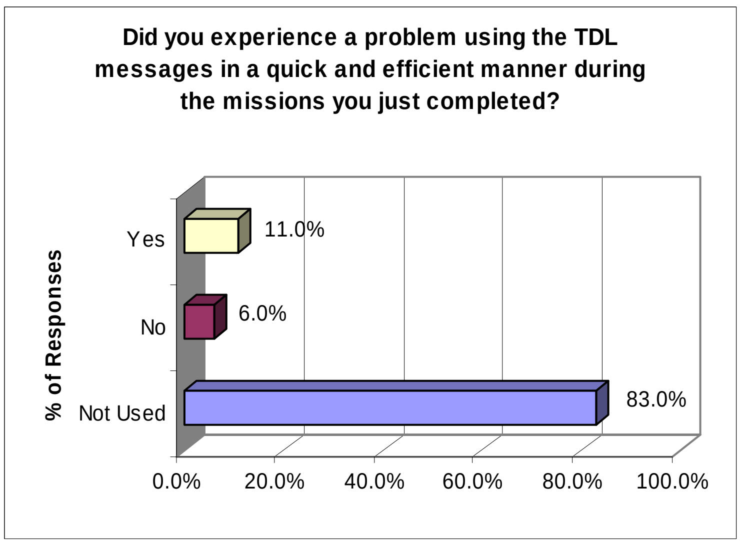



Did you experience a problem using the HSDH in a quick and efficient manner during the missions you just completed?
% of Responses
Yes
No
Not Used
11.0%
6.0%
83.0%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%


Did you experience a problem using the DMS in a quick and efficient manner during the missions you just completed?
% of Responses
Yes
No
Not Used
61.0%
33.0%
6.0%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%


Did you experience a problem using the WCA displays in a quick and efficient manner during the missions you just completed?
% of Responses
Yes
No
Not Used
22.0%
11.0%
67.0%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%


Did you experience a problem using the EICAS in a quick and efficient manner during the missions you just completed?
% of Responses
Yes
No
78.0%
22.0%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%


Did you experience a problem using the TDL messages in a quick and efficient manner during the missions you just completed?
% of Responses
Yes
No
Not Used
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6.0%
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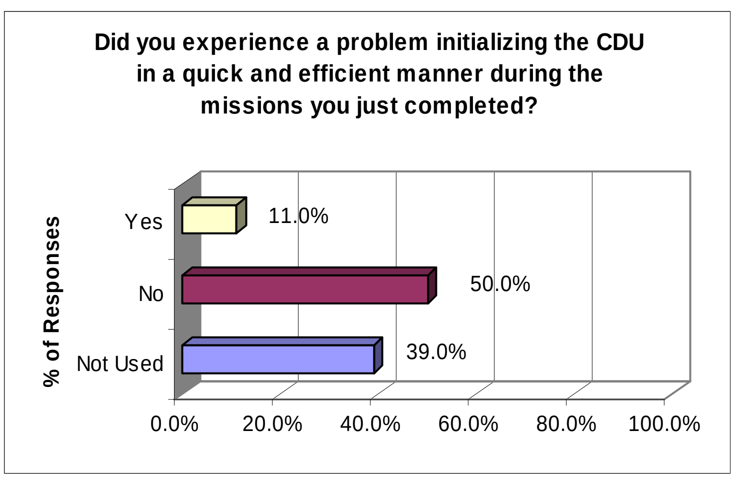
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%


Did you experience a problem initializing the CDU in a quick and efficient manner during the missions you just completed?
% of Responses
Yes
No
Not Used
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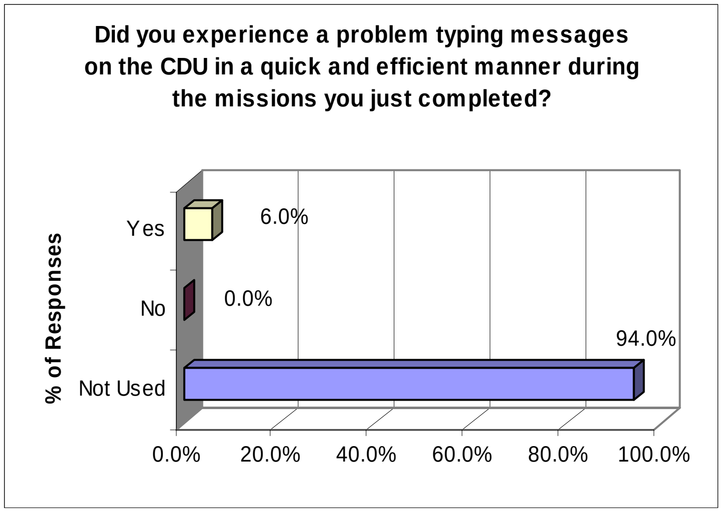
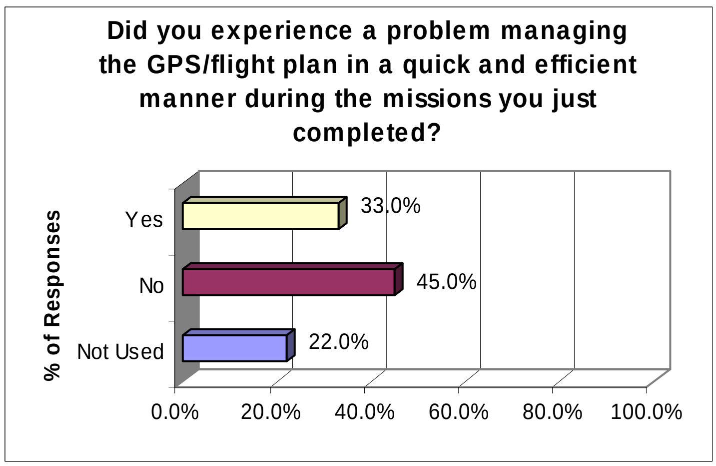
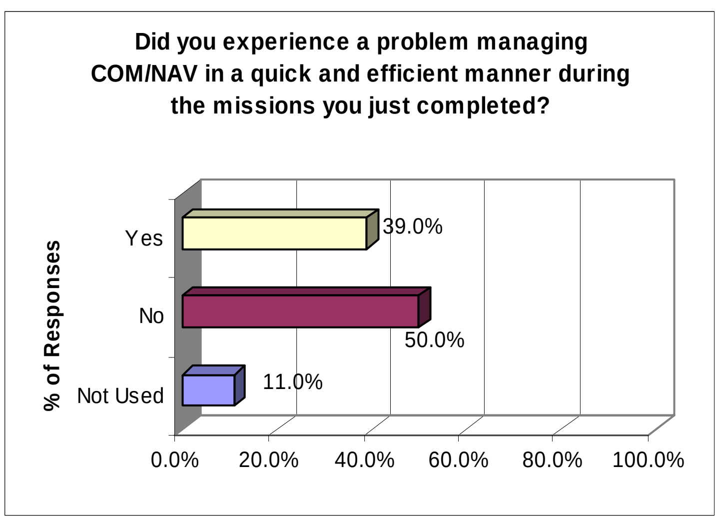
50.0%
39.0%
0.0%
20.0%
40.0%
60.0%
80.0%
100.0%







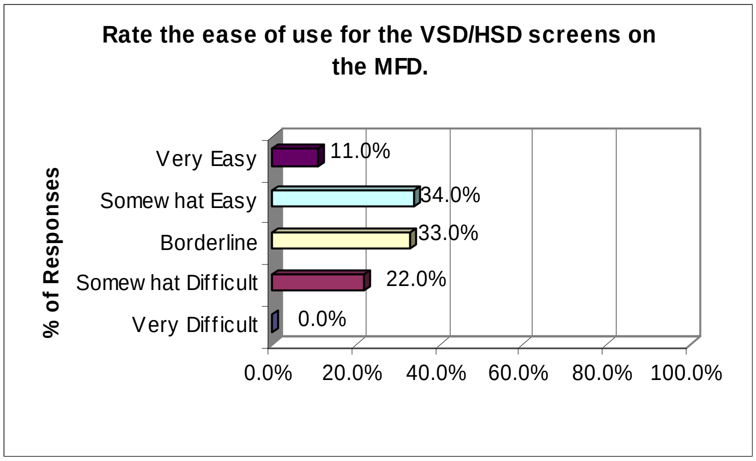
- Can't set-up for next part of flight plan without changing information on pilots display.
- CDU – Menu structure too deep and non-intuitive.
- CDU – Pilot flying can't not set altimeter setting or not see what it is.
- CDU – Too many button pushes to set altimeter setting.

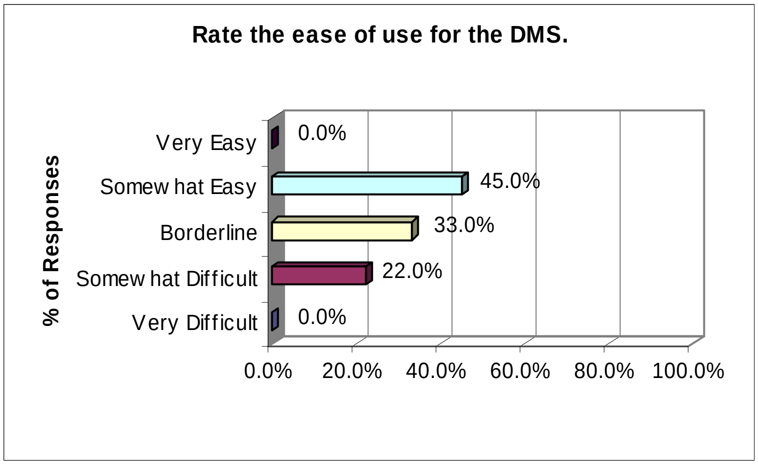
- COM/NAV/IFF – Workload too high. Also a heads-down operation. Several button pushes to get to a OM or NAV preset page. Workload intolerable, bit too high for simple tasks.
- Could not remember how (where to go) to set new altimeter settings. Just confirming altimeter settings required 2 button pushes.
- Could not see HSD indications with DIGMAP (digital mapping system) running in the background. White on white does not work.
- Determining Com/Nav presets requires several button pushes. Appears to take less time if I "fat finger" them.
- DIGMAP – Disappeared a couple of times. No overlay of flight plan if displayed on top (1/2 page).
- DIGMAP – Menu and overlay structure confusing. Configured by trial and error.
- Digmap – No aircraft symbol if on top half of display.
- DIGMAP – Overlays and scaling is confusing. EICAS needs one all-inclusive page.
- DIGMAP – The overlays don't have enough contrast between the overlays and the map.
- DIGMAP – With the jog map selected, the HSD compass ring and flight plan depiction were hard to distinguish on the map. The white lines were hard to see. It would be nicer to have a shadowed line or a different color.
- DIGMAP – Zoom feature is buried too deep in menus. Could not find immediately. Zoom ratio is only displayed on one overlay. Should always be displayed.
- DMS – Problem occurred due to my lack of familiarality with the system. Many menus and it is difficult to work the zoom feature.
- EICAS – Can't put all functions where you want. Fuel should always be displayed on EICAS or HSD. Torque was redundant and not necessary.
- EICAS – Don't need torque. Could not be out in the upper left MFD even though an HSD was up in the upper right MFD. Add fuel to the EICAS page (burn rate and total).
- EICAS – Engine instruments and caution/advisory on separate pages.
- EICAS – Engine/transmission bar scale page needs updating! Need fuel bar/window, Ng bar! Must be able to put this page where you want it (e.g., inside top MFD).
- EICAS – Need one well designed EICAS with engine and transmission instruments, caution/advisory, and fuel on one page.
- EICAS – Same as WCA notes. Also, the EICAS only displays digital Ng. This is not good enough. Should have Ng tape to aid in quick readability of Ng trend info.
- EICAS – Too many displays to see what I need. Needs to be one page.
- EICAS – Too many pages to display the information needed (e.g., 1 page should be able to show all systems and fuel). Designed properly, 1 page can show all fuel, systems, and cautions/advisories.
- EICAS – Too many pages to see all that is required for flight. Need fuel bars, Ng bars on engine/transmission bar graph page, and page must be able to be put in a top window of MFD.
- EICAS – Torque meter is redundant. Replace with total fuel and burn rate.
- EICAS – Unable to monitor entire aircraft condition on 1 page.
- EICAS needs to be able to move to upper left (inside) MFD. Also, needs to have fuel bar on it, with a digit fuel flow and amount window. Get rid of TQ bar – it's already on the VSD. Move TQ req/avail to bottom of TQ bar on VSD.

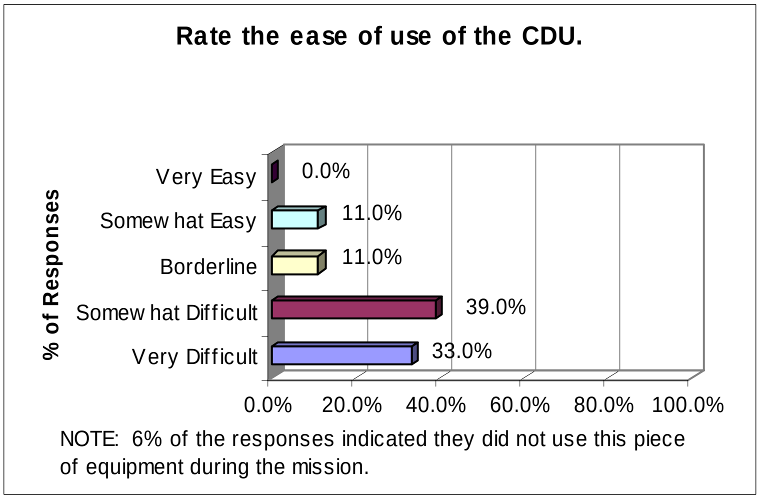
- FLT Plan – I could not figure out quickly how to go “direct-to” to a preset ACP point. I had to use the MFCU.
- GPS/FLT Plan – Again, kind of workload intensive. The workload rating is not unbearable, just too high for some of the required tasks. Also primary “heads-down” operation.
- GPS/FP – Too many button pushes to get things accomplished. LSK labels not intuitive – must know where something is in order to select it.
- HSD – ACP, ADF, VOR, TACAN needles should be different colors. Need heading bug without flight director.
- HSD – CDI was not directional when flying outbound on VOR course.
- HSD – Compass rose and bearing pointers difficult to read with light colored background. Some map backgrounds useless with compass rose. No reference bug available for use on compass rose. NAV pointers all need to be color coded.
- HSD – Compass rose and CDI pointers very hard to read with light colored background maps. Compass rose needs four letter cardinal headings depicted on compass rose (N, S, E, W).
- HSD – Configuring the NAV information on the HSD is confusing. There are too many choices (CDI has at least 3 choices) to make a quick accurate selection at this level of proficiency.
- HSD – Could not bring up heading bug without engaging flight director.
- HSD – Could not determine how to display the flight plan (ACP) route overlayed on the HSD to see my route.
- HSD – Could not get VOR or ADF big pointers to come up. All bearing pointers being the same color is hard to distinguish between them. I believe that FD and overlays should be combined into one page. I would like to see the MFK control the last thing I touch on the MFD bezel.
- HSD – If you have a VOR bearing pointer and ACP bearing pointer both on and they point to the same location, it is hard to tell if one or the other or both are on. The needle head displays both “D” and “V”.
- HSD – Need easy way of setting hdg and crs bugs.
- HSD – Numbers along the compass ring were too small to distinguish quickly.
- HSD – Selecting bearing pointer modes and CDI modes is confusing on your own side, not to mention trying to determine what the other pilot has set.
- HSD – The CDI and compass pose too hard to read with light background maps. Could not see CDI with Jog up
- HSDH – The corrective action cues were not intuitive. Could not maintain position using cues.
- HSDH – The hover page displayed the donut 90 degrees off to the right of actual aircraft movement. Also found it unnatural to be trying to focus inside on a hover page when trying to hover. Especially with my hover page on lower half of outbound MFD.
- I would like to see more lines below 50% on the TQ strips. When performing the HIT check, I usually use the strips to get close, then digits to get accurate.
- IFF – Change mode 3A should be a top-level function.
- IFF – Setting mode 3A is too deep into the menus.
- Manage COM/NAV/IFF – Paths to radios and Navaids are not intuitive. Too much scrolling and not enough one touch hot keys.

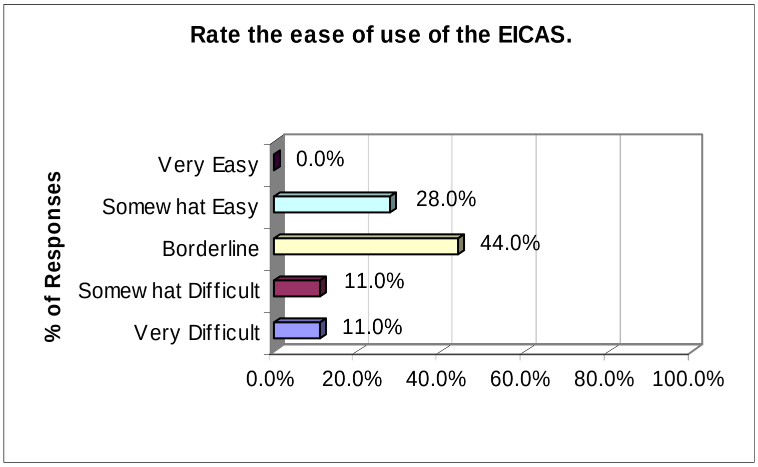
- Manage flight plan – Could not get flight plan overlay on left HIS.
- MAP – Very difficult to find the zoom feature. Not intuitive.
- MFD – With CDI(VOR) up – when selecting FD and then go back to Other pages, CDI goes off.
- Roll command and pitch command indicators are prominent on the VSD. I kept trying to fly them back to the wings instead of the reverse. If they could be shown in the background – behind the wings, I believe it would have been better for me.
- TDL – Using MFD it was too long. Too many screens to go through. The net I was sending on when using the MFD did not link to the radio I had set and displayed on the MFD. I had to reset each time. It should remember the net I had last.
- The velocity vector on the VSDH was 90 degrees off. The doughnut was also inaccurate.
- VSD – After changing airspeed value for Flight Director, my airspeed bug remained on old value until separately loaded into my CDU.
- VSD – Angle of bank indicator opposite. No Kollsman window.
- VSD – Flight director altitude mode was incorrect.
- VSD – Had difficulty identifying a slight bank of the aircraft and with the turn indicator displaying opposite of the turn direction, corrected to the wrong direction frequently.
- VSD – Need fuel, Kollsman window, and Nr, Ng, and TGT pop-ups
- VSD – Need to combine FD and overlay. PFD needs fuel, Nr, Kollsman window, TGT, and Ng pop-ups.
- VSD – Processed data was confusing in a 20 degree and greater angle of bank. Maintaining airspeed using only processed data was impossible.
- VSD – Roll indicator indicates wrong direction for roll out. Bar scales for a/s and alt, but round type gages would be easier and quicker to use. GS readout needs to be below a/s tape. No altimeter window caused pilot to not know what was set.
- VSD – Same as my previous comments + fuel and altimeter setting needs to be displayed.
- VSD – Setting FD modes and values on the VSD is complicated. Must use the MFD and the CDU (or CDU and MFK). This is too much work to do a simple task such as a heading or airspeed change.
- VSD – Slow to pick up on radar altimeter cues in low level flight environment
- VSDH – Hover point not directional! Should be able to move towards hover point depiction, not away!
- VSDH – Velocity vector and acceleration cues were not working.
- WCA – Could not acknowledge the main transmission chip.
- WCA – Need to integrate caution/advisory onto one well designed EICAS.
- WCA – Too many pages. A pop-up WCA summary page, well designed, is all that is necessary. Too many page selections to get the information.
- When sending position reports, the frequency should remain constant until changed by the crewmember. Having to select A2C2S and 439 each time added 9 button pushes to the 11 it takes to send a position report.

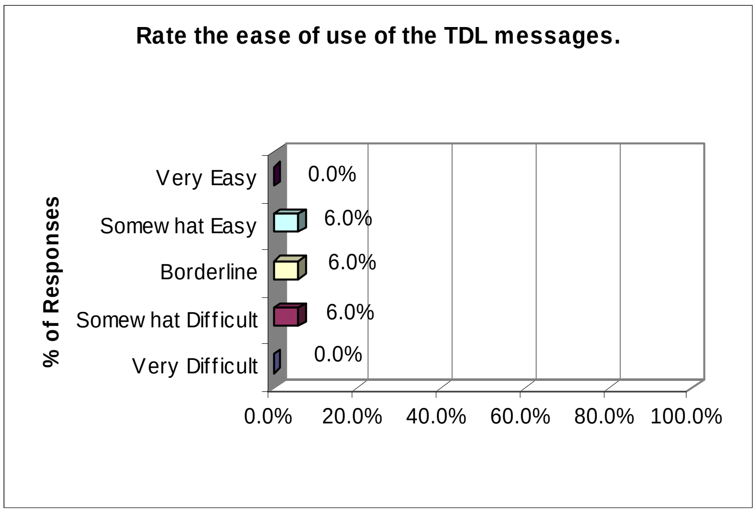
PV2 Comments

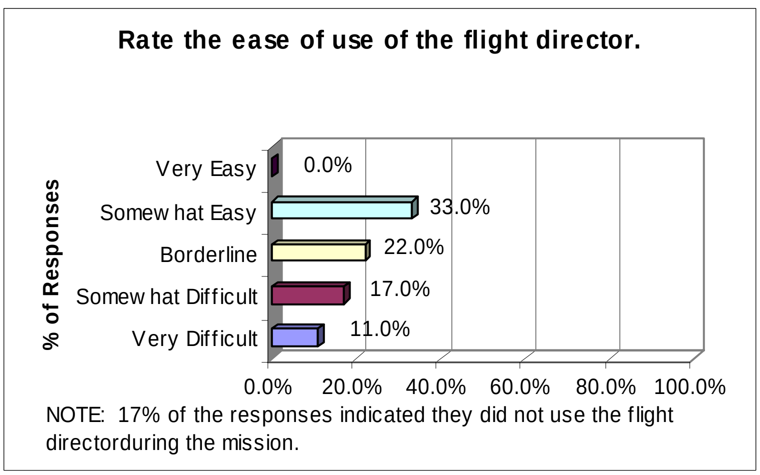










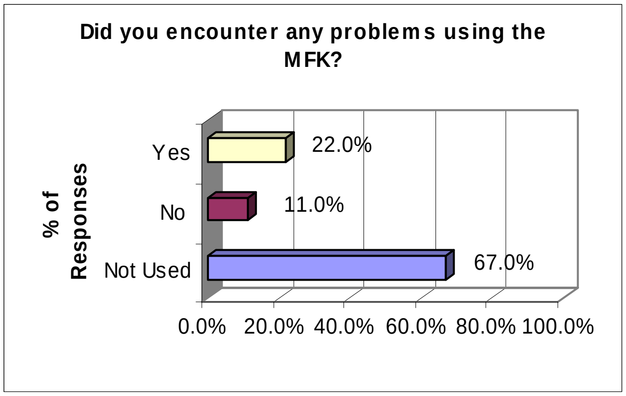


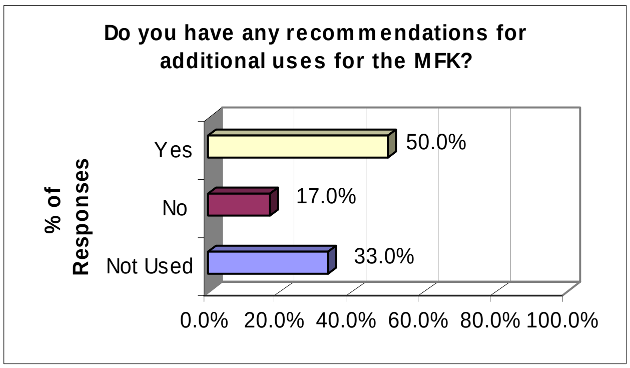
- Barometric altimeter setting page is not intuitive.
- CDU – Awkward and time consuming to use with the MFK. Going from MFK to CDU and then to MFK again takes too long and will not be used effectively. There must be more hot keys on CDU (e.g., altimeter hot key, CDI hot key, transponder hot key) or additional space with hot keys.

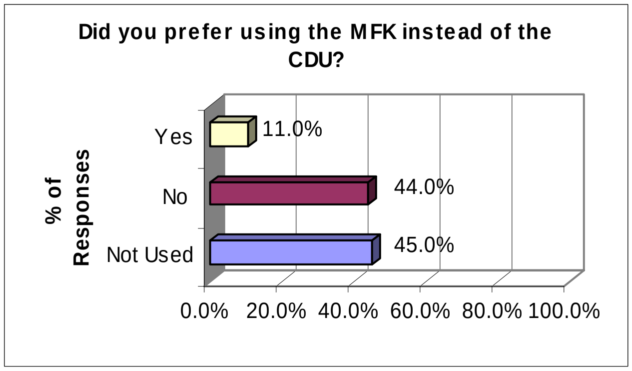
- CDU – Data entry for the pilot on the controls is too difficult for the basic data entry functions (e.g., make the MFD slaved to hot key functions only such as altimeter, heading, course set display.
- CDU – LSK labeling not intuitive. Some “top-level” functions (e.g., altimeter buried too deep).
- CDU – Menu intensive. Too many layers. Many functions that should be “top-level” are 2 or 3 levels down (e.g., altimeter setting, selecting a new heading, etc.). Some keys/locations not intuitive (e.g., IDX, PRO/PATT/ACPs).
- CDU – Menus too deep and not intuitive (i.e., altimeter setting, direct-to, ACP locations).
- CDU – Not intuitive – Menu structure requires rote memorization.
- CDU – The limited MFK was cumbersome to use with CDU lending data entry only to the CDU keyboard. Primary functions are buried too deep. Should have had more hot keys.
- CDU – Too many button pushes to get to where you need (e.g., setting WP/VOR course – several button pushes compared to a twist of a knob on the A/L, try to set altimeter, etc).
- CDU – Very heads-down, non-intuitive menus. Setting FD heading, course, altitude, and airspeed is very cumbersome.
- Com/Nav presets are buried too deep to be effective. I wrote presets on my kneeboard prior to flight to get around all the button pushes.
- Could not remember where to put in new altimeter settings. Should be on mission page – not hidden under index.
- DCU – Menus are not intuitive and too deep.
- DIGMAP and FD – Too many choices and labeling not logical. I don’t think additional display space is required. Better, more logical use of the space available is a better answer.
- DMS – All displays need aircraft symbol.
- DMS – Bezel keys should show next page not current.
- DMS – Overlays complicated – too many layers.
- DMS – Zoom needs to be relooked. Zoom % should be on every page and is too difficult. Buried too deep to be functional.
- EICAS – Need one all-inclusive EICAS page.
- EICAS – Need one well designed page with engine/transmission instruments, caution/advisory, and fuel on one page.
- EICAS – Too many button pushes to see all that needs to be used in flight (e.g., eng/trans instruments, fuel).
- EICAS – Too many pages. All engine indications, cautionsand advisories, and fuel can be put on one page. Why have several? This is wasted space – wasted time for the pilots – very inefficient.
- EICAS – Too many pages. Need one page with all systems, caution/advisory, and fuel.
- FD – Need easier way to set commanded a/s, alt, hdg, and crs that is not so heads down.
- FD – Too cumbersome to engage. Too cumbersome to change values. Too cumbersome!
- Flight Director – Too much work to use the FD. Also, no capability for using the “heading bug” without a FD mode engaged.
- Getting the DIGMAP up on the top inboard MFD was difficult.

- Having to push HSD to get out of the TDL message was not intuitive.
- I found it still confusing to remember where items are located. Best example today was the altimeter setting. I did not think “index”. Also, I felt confused on fast method of changing radio frequencies if given one from ATC that was not a preset.
- If the EICAS can be reconfigured and can be allowed to move to any location on any MFD, then 5th MFD is not needed.
- Placing a preset VOR or ADF into the active was too many steps. Having to go through menus to presets then back to enter the preset # again to activate. I would like to be able to activate the preset from the list.
- TDL – Too long in the cockpit going through screens and the net problem previously mentioned.
- VSD – Must press too many buttons – labels not intuitive.
- VSD off the map would not bring up the map. Could have been a software glitch.
- VSD/HSD – FD too heads down require use of both the MFD and CDU. Overlays are confusing.
- VSD/HSD – Not enough information on each page. Requires page switching.
- VSD/HSD – Setting up FD and overlay confusing. Need heading bug.

PV3 Comments

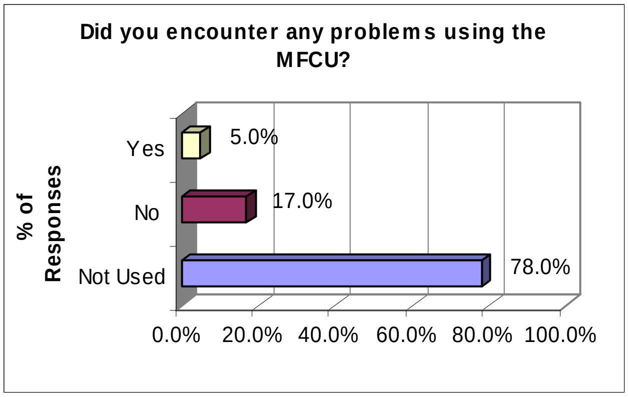


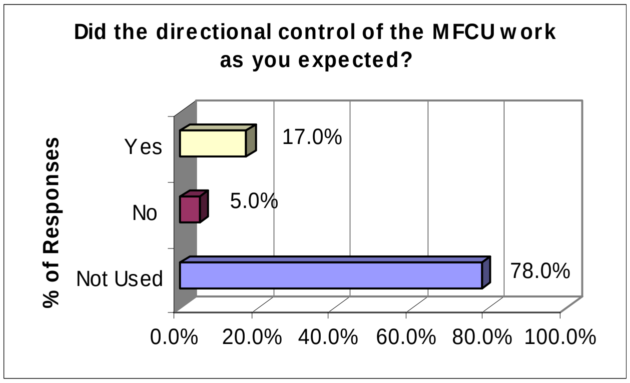


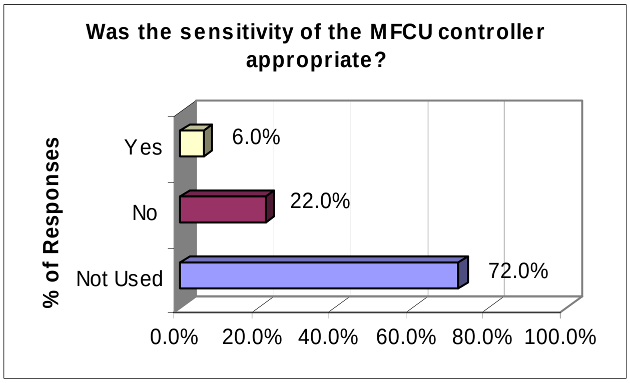


- It is quicker to enter data directly into the CDU. Responds too slow to pilot input (increase sensitivity). I preferred the CDU.
- Recommendations – Link the MFK to hot key functions only. These hot keys would be for critical functions (e.g., altimeter, CDI, transponder, etc) and slave the MFK to those functions only. This is intuitive and would decrease pilot workload. The current implementation of the MFK increases pilot workload.
- Use MFK for altimeter settings.
- By the time you go through the CDU menus to activate the MFK for the intended purpose, it's easier to continue typing the information into the CDU.
- Would prefer to see multiple, single-purpose knobs.
- I don't think this is a useful knob as it is now. It is much easier to manually enter the desired parameter via the keyboard than to use the MFK.
- MFK was intermittent. Should be able to use it to set or move a course/heading bug.
- Slave the MFK to hot keys. Use only for primary and basic functions. If you have to touch the CDU at all, then it is easier to fat finger the numbers in on the CDU. I would find it easy and intuitive to push an altimeter key on the MFD then turn the MFK to set it.
- By the time you select the proper CDU page to enable the proper MFK function – it was easier tp just continue using the CDU and enter the info. Implement multiple knobs with single functions that are always enabled.
- Independent heading bug on each pilots HSD controlled by MFK.
- Altimeter setting would also be a good use if barometric setting was on each pilots VSD.
- MFK adds to workload. It is easier to type the desired value in.
- Allow it to be used with a "hot key" function from MFD. Like setting altimeter, moving heading bug, or course.
- Get rid of MFK or slew it to a specific primary flight data function. It is inefficient in it's current capacity. Pilots will use the CDU input pad. Instead of buying buttons and knobs for a Kollsman window, heading bug, course set display – have one MFK that works for these functions and maybe a couple other functions only.
- Incorporate multiple single use knobs instead of one multi-use knob. Since you have to enable the MFK's function with the CDU – it's easier to keep typing.
- Sim Problem – I could not keep scrolling down – it seemed like it got stuck.
- Allow it to control what you touch on the MFD bezel.

PV4 Comments

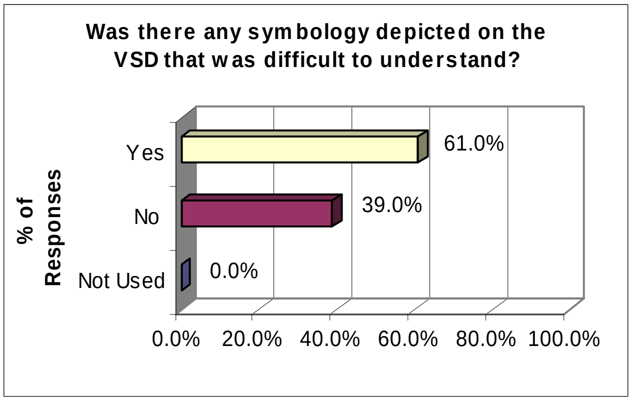


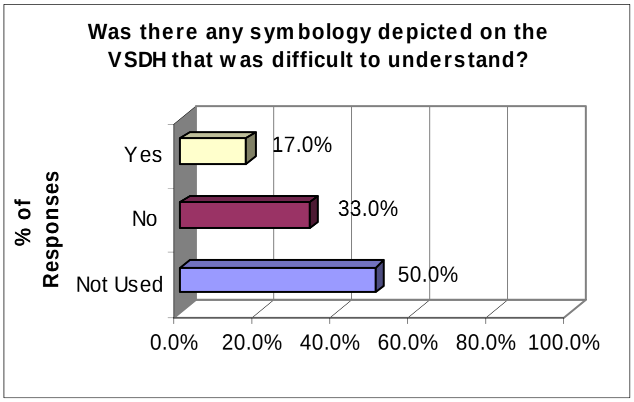


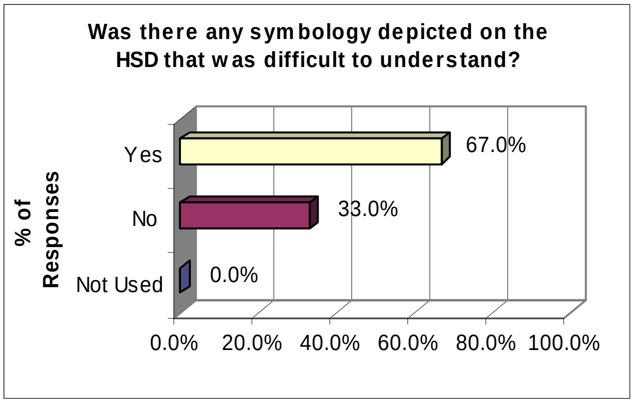


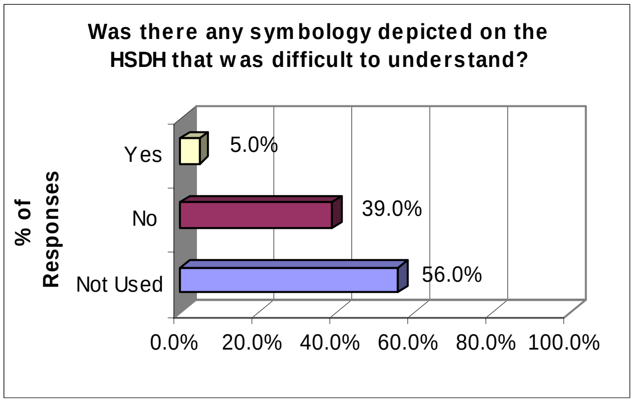
- Not used, but when it is used, it slew cursor way too slow and should be progressive speed with pressure.
- Needed to be variable speed with highest speed faster than the current implementation.
- Having the bug start at present location was good.
- Cursor needs to move quicker.

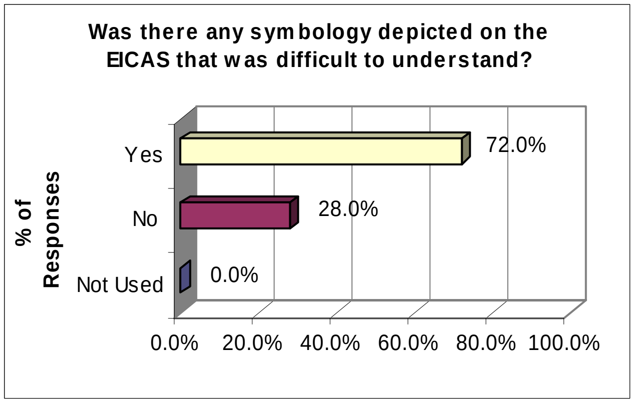
PV5 Comments

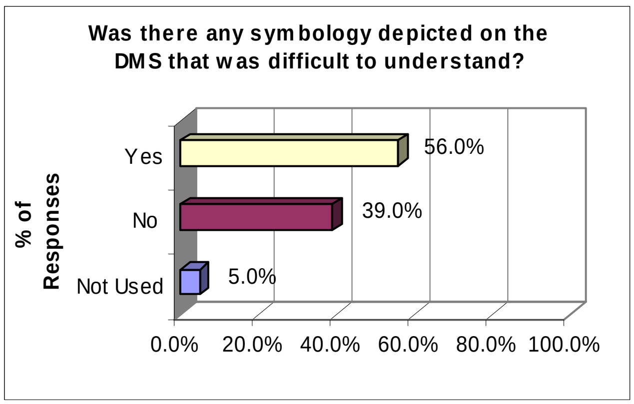


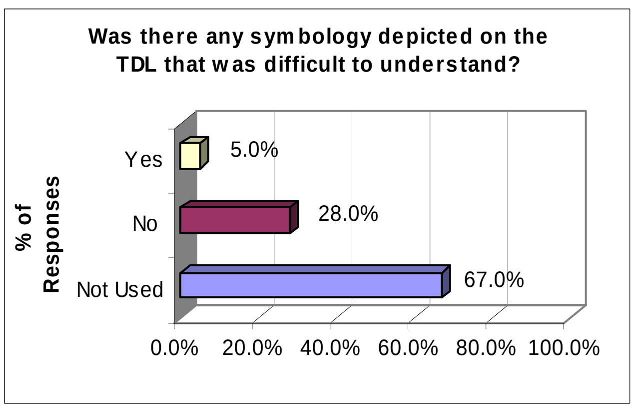










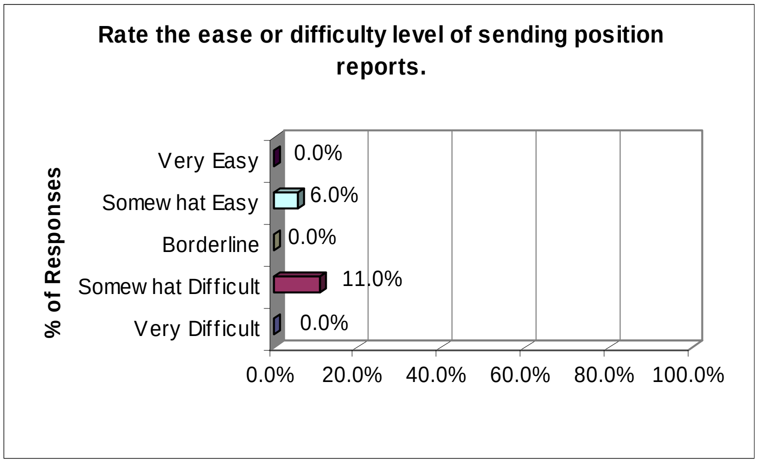


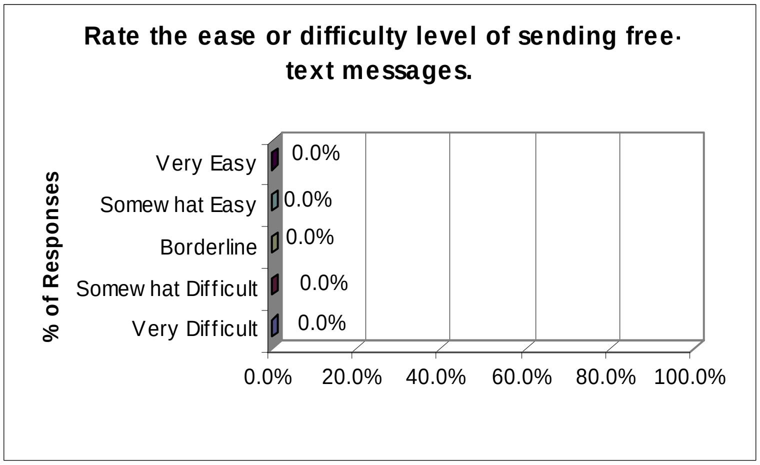
- DIG MAP – White route, aircraft, HSD, HSDH hard to read overlaid on jog map.
- Digital Map – I found the map pages and overlays difficult to find. Make zoom controls available every time a map is displayed. More simple map features may be better.
- DIGMAP – Finding zoom function too difficult – never knew what scale I was in.
- DIGMAP – Menu system and overlays confusing.
- DIGMAP – Overlay menu structure confusing.
- DMS – Course lines are very difficult to see on a jog. Lines need to be shaded. (currently white lines on white background).
- DMS – Need aircraft symbol on all digmap displays.
- DMS – Overlays not enough contrast.
- DMS – Zoom hard to read. Zoom % should always be displayed.

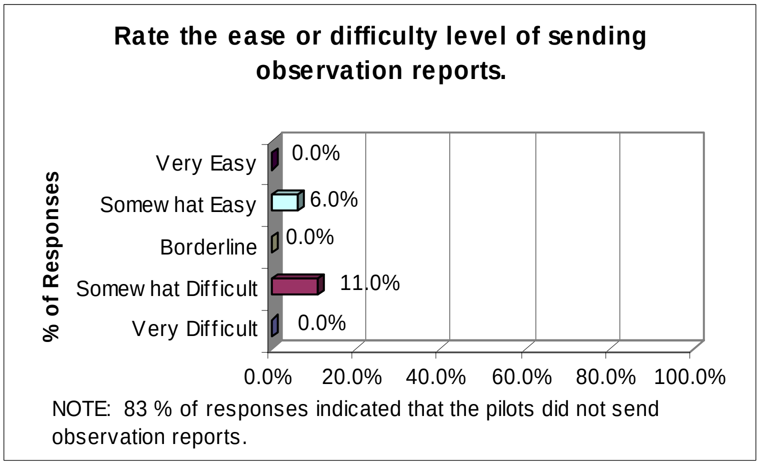
- EICAS – Need a strip for Ng – in my scan, I could see the strips but had to focus harder to see Ng.
- EICAS – Need one page with all the basics (e.g., add fuel, bars to RPMR, eng, trans page). Must be able to move to upper inside MFD. Otherwise you need 5th MFD.
- EICAS – Need one well designed EICAS page with all information on it.
- EICAS – Not well designed – should be one page.
- EICAS – Too many button pushed to see all that is needed on a flight. Ng hard to read on a quick look in by pilot.
- EICAS – Too many button pushes to see all. Need to consolidate onto one good, useable page.
- EICAS – Too many pages
- EICAS – too many pages.
- EICAS – Torque is redundant and should be better utilized with fuel and fuel flow. Can't put EICAS page in any position you want.
- EICAS – Torque is redundant. Was not able to place screen where I wanted it.
- HSD – Cardinal directions are too small. I have to concentrate and focus harder to see them.
- HSD – Compass rose too light – can't read on light background.
- HSD – Compass rose/CDI too "white". Needs to be darker for light background maps.
- HSD – Hard to see CDI bearing pointer with light colored background. Also hard to see multiple bearing pointers due to all being one color.
- HSD – Need different color for ACP, ADF, VOR, TACAN needles.
- HSD – Numbers on compass hard to read.
- HSD – Numbers or cardinal displays should be larger. Everything is very difficult to see over a jog map or even a black screen.
- HSD – Too small of numbers on the compass ring. Bearing pointers need to be different.
- HSD – With more than 1 CDI or bearing pointer selected, hard to tell one from the other. Suggest different sizes, FAA/TSO standard colors.
- HSD difficult to set-up CDI/bearing information and difficult to interpret (Different color pointers may help this).
- HSDH – Donut 90 degrees to the right of the hover movement.
- Need color code bearing to pointers. Remove donut from FD. Need one all-inclusive EICAS page.
- VSD – Angle of bank pointer
- VSD – Angle of bank pointer going opposite of aircraft causes disorientation.
- VSD – FD indications harder to follow than in legacy aircraft. Roll indicator turns opposite of pitch ladder bars. Very disorienting.
- VSD – I had trouble with altimeter reading. Reported 6000 feet instead of 600 (actual).
- VSD – No way to tell what altimeter setting is!
- VSD – Processed data is not intuitive – airspeed especially difficult to determine in a bank.
- VSD – Recommend removing the "doughnut" from the FD.
- VSD – Turn indicator is opposite of aircraft bank. This is confusing.
- VSD – Turn indicator moves opposite of aircraft bank – confusing. Need an Nr strip.

- VSD – Would like to have fuel on-board displayed. This would prevent me from going through another MFD, two pages deep just to see fuel status.
- VSDH – Completely unintuitive – input commands make no sense.
- VSDH – Hover point not directional (we moved wrong way).
- VSDH – Not working correctly.

PV6 Comments

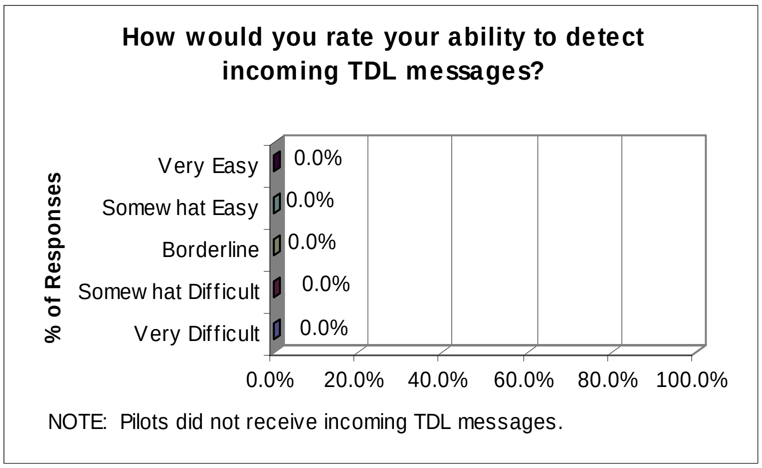


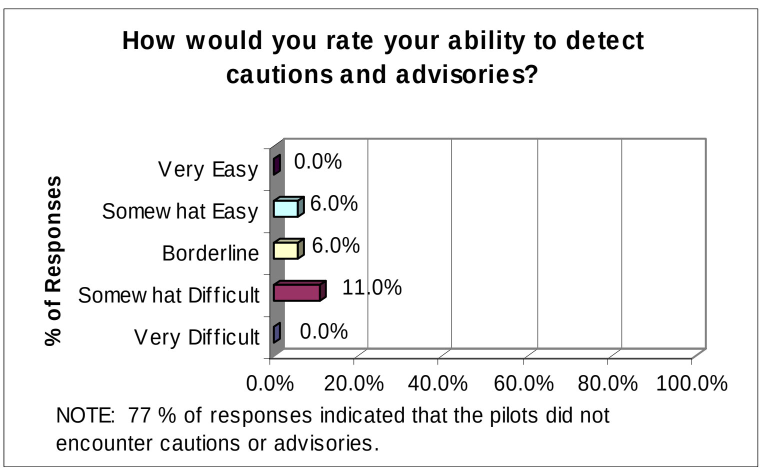


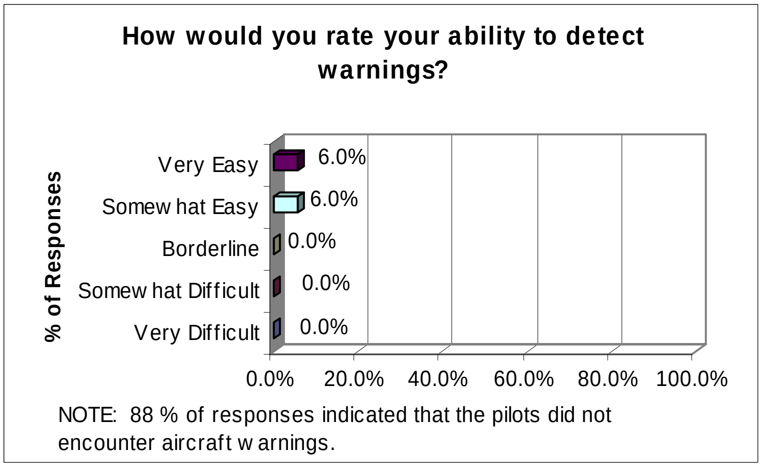


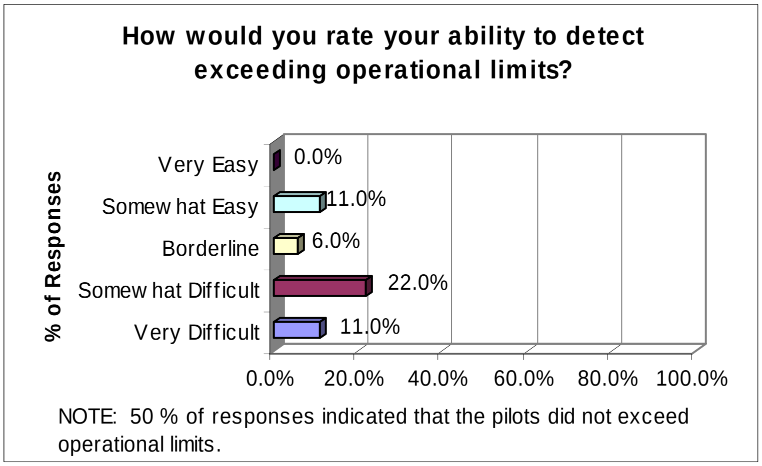
- Did not have the time to send a free text message on the tactical mission. That would have been way too much time inside the cockpit.
- Position Reports – Too many button pushes away. The top-level button to get to the menus is not intuitive. System makes me think of aircraft systems not messages. The net # and Net ID name did not match what we had active in the radio. I had to reset each time.
- On the MFCU, I did not see "Position Report" but it was easier using the MFCU to send messages.

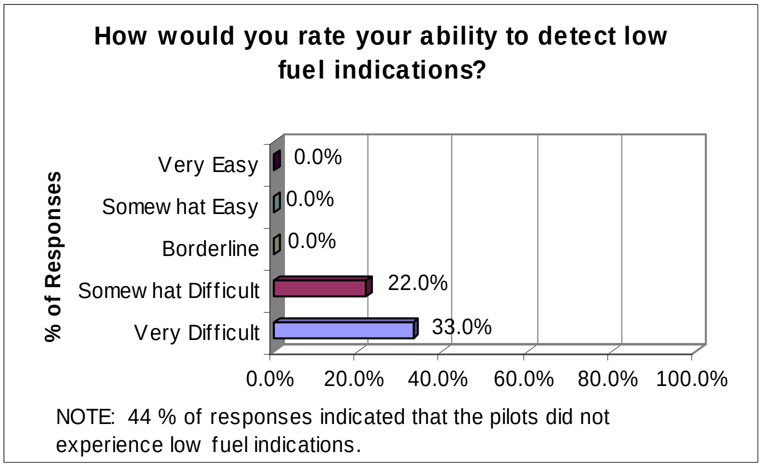
PV7 Comments







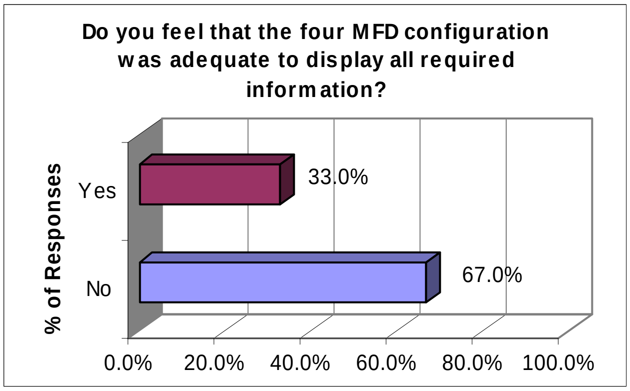




- Low Fuel – It is impossible to determine low fuel unless you have the fuel page selected. Recommendations – Make fuel indications static on additional display space or put fuel on a higher priority page such as the HSD page or the systems page. Fuel is the most limiting factor in how we perform Army missions – so who exactly chose to de-prioritize it by putting it away and out of sight. This needs much more attention.
- There is no fuel quantity indicator present unless you pull up a big line drawing and leave it up. A fuel strip should be present on the VSD.

- Operational Limits – You don't know you're about to exceed TGT or Ng from the PFD. If no EICAS page is selected, exceedance may be unknown. Ng has no strip (only digits) on EICAS page.
- Can not see changing trends to engine/transmission systems (bar graphs) or fuel. Must have that page up, too many button pushes. A pilot can't wait until a system goes past a limit.
- Fuel should never be out of sight – never. Put on the systems/EICAS page at a minimum.
- Caution/Advisory – Need one good page integrated into the EICAS page.
- Operating Limits – Need Ng, TGT pop-ups on PFD. Need fuel on PFD.
- I did not have the fuel page up. It would be very difficult for me to see a low fuel condition prior to the caution light.
- EICAS – Will not see a "trend" without engine/transmission bar graph page up all the time. Will have to wait for a limit to be exceeded before getting an alert. Will not know fuel is getting low until "low Fuel" light comes on. This is unacceptable. Must be able to see trends.
- Low Fuel – I want to see fuel at all times. Low fuel warning is not an engine or systems warning. You can most of the time get the aircraft back into limits, but you can't do that with fuel – so why use the same indicating system for fuel and systems?
- Poor design and never should have been designed this way. Big mistake.
- Easy to see TRQ, but not other indications of limits being reached.
- Would not know of low fuel unless the fuel page is up – unless we were already in a low fuel situation.
- Need all-inclusive EICAS. Without TGT and Ng pop-ups, you can exceed and never know it.
- C/A – Borderline. Only see chip light. No indication of oil pressure, temperature, etc. Unless you slew through EICAS page.
- Limits – Hard to spot trending on Ng. Must have dedicated EICAS pages up and rotate through.
- Fuel – Poor design. Make one EICAS page.

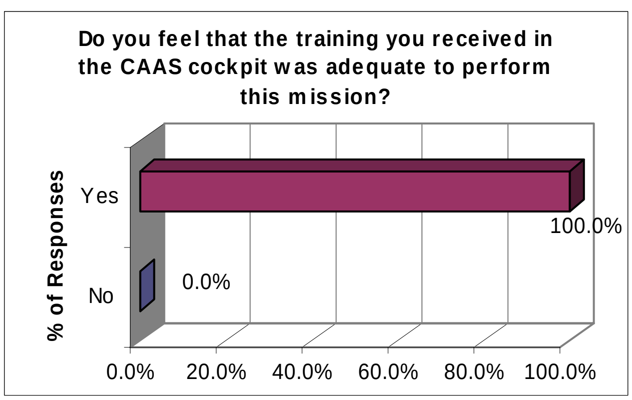
PV8 Comments



- Only if you update EICAS page and be able to move it to inside upper MFD.
- In the current configuration with current problems, you need another display. See previous comments.

- Not without design changes. I would want to see fuel quantity, altimeter setting, and Nr strip on VSD. Be able to place engine instruments on top of one MFD. We don't need a drawing of the aircraft on a fuel readout. Just give us the strips and numbers.
- PFD needs pop-ups for pending engine exceedance. EICAS needs to be one page, not 4. Without significant changes, a 5th MFD is definitely required.
- Another MFD was required for this mission and it's required workload.
- Not in current configuration. If designed properly, 4 MFDs can be adequate. If the displays can't be changed, then may need a 5th MFD.
- 5th MFD is not required if EICAS pages can be changed.
- Need more space to display fuel, Kollsman window, and hot keys or fix the issues addressed.
- Need to redesign PFD and EICAS pages.
- Not in its current available page format addition of info (i.e., comments we discussed in AARs this week need to be incorporated or else a 5th MFD needs to be added. If we can't change page format the 5th MFD would be better than just 4.
- I don't think a 5th MFD, if it has the exact same displays, will alleviate the problem. You cannot get a VSD, HSD, Systems, and WCA and Fuel on 2 MFD's. This is unsatisfactory and a big problem with this design. Putting an identical 5th MFD is not a solution – it is a reaction to a poor design.
- But software needs to be updates for what is displayed and where.
- In current configuration with current software, you must have a 5th MFD.
- Don't add a 5th MFD. Fix the ones we have.
- Not in current CAAS page format. Both the PFD and EICAS need additions discussed in AAR's. EICAS must be one catch-all page showing all. If fixes are incorporated into CAAS pages I think 5 MFD's are not needed.
- I think a total redesign is called for or use displays from UH-60M baseline.

PV9 Comments



- Training was adequate. Proficiency will be an issue. Pilots will have to use the system daily to remember how to get to everything. Finding things is not always intuitive.
- More time to fly the pitch and roll command indicators. Deleting the doughnut from inside the CMD indicators may also help.

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Glossary of Acronyms

AAR	after-action review
ACP	air control point
AMRDEC	Aviation and Missile Research, Development, and Engineering Center
AOI	area of interest
APEX	Advanced Prototyping, Engineering, and eXperimentation (Laboratory)
ARL	Army Research Laboratory
ASL	Applied Science Laboratories
ATM	aircrew training manual
ATTC	Aviation Technical Test Center
BHIVE	Battlefield Highly Immersive Virtual Environment
BWRS	Bedford Workload Rating Scale
CAAS	Common Avionics Architecture System
CDU	control display unit
CPC	Comanche portable cockpit
DIGMAP	digital mapping system
EDS	engineering development simulator
EICAS	engine instrument caution advisory system
EUD	early user demonstration
HFE	human factors engineering
HSD	horizontal situation display
IFR	instrument flight rules
IIMC	inadvertent instrument meteorological conditions
IMC	instrumented meteorological conditions
LEUE	limited early user evaluation
LUT	limited user test
MANPRINT	manpower and personnel integration
MFCU	multi-function control unit
MFK	multi-function knob
MEDEVAC	medical evacuation
MFD	multi-function display
OTW	out the window
PFD	primary flight display
PO	Product Office
PVI	pilot-vehicle interface
SA	situational awareness
SART	Situational Awareness Rating Technique
SSDD	Systems Simulation and Development Directorate
SSQ	Simulator Sickness Questionnaire
TDL	tactical data link
TRADOC	Training and Doctrine Command
TSC	tactical steering committee
TSM	TRADOC System Manager
UH	utility helicopter
VFR	visual flight rules

VMC	visual meteorological conditions
VSD	vertical situation display
WSRT	Wilcoxon Signed Ranks Test
XP	experimental test pilot

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